HOW IT WORKS

The Curiosity Box
EXCLUSIVE OFFER INSIDE

14 EXPERIMENTS THAT CHANGED THE WORLD

HOW IT WORKS

THE MAGAZINE THAT FEEDS MINDS

WILL SMITH'S EPIC EARTH
Behind the scenes of Nat Geo's new show

AMAZING CUTAWAYS

SCIENCE
Why do your ears pop?

HISTORY
Inside Hampton Court Palace

TECHNOLOGY
Apple HomePod teardown

SPACE
DEADLY SOLAR STORMS
How to predict space weather

+LEARN ABOUT

TECHNOLOGY AIR PURIFIERS **EDIBLE CUTLERY** BAGPIPES SCIENCE DIALYSIS **NAME FACTS** ENVIRONMENT CREATIVE CREATURES **COTTON** TRANSPORT AIRBUS BELUGA **TARMAC** TRANS-SIBERIAN RAILWAY HISTORY **WOMEN'S SUFFRAGE** THE GOMPERTZ LAW SPACE **JUPITER'S CYCLONES** ULTRALUMINOUS X-RAY SOURCES

FUTURE
ISSUE 112

POWERBALL® GYROSCOPES

DEVELOP YOUR OWN GRAVITATIONAL FORCES...LIKE TINY SPINNING PLANETS

280 Classic
The Entry One £19.99

280 Autostart Classic
The All Round One £29.99

280 Signature Pro
The Exquisite One £39.99

280 Autostart Pro
The Best Selling One £44.99

Titan

The Most Powerful One £129.99

280 Autostart Fusion
The Amazing One £49.99

powerballs.com

A zero-gravitational training aid for NASA astronauts, Powerball® delivers strengthening and rehabilitation for the arms & wrists unlike anything else on *(or off)* this planet. But don't spin it too fast...or you just might create a black hole!

ISSUE 112

WELCOME

The magazine that feeds minds!

We love a bit of future-gazing here at **How It Works**, so this month we're considering how tech will have transformed our daily lives by the year 2050. If increased automation does indeed lead to us receiving a Universal Income, then I for one welcome our new robot overlords...

When Hollywood tackles a subject, it goes *big*, and nature documentaries are no exception. The epic *One Strange Rock* is produced by Darren Aronofsky, hosted by Will Smith and includes the unique insights of a team of inspiring astronauts. We go behind the spectacular scenes of the show that is re-introducing us to planet Earth. Tune in to National Geographic on Tuesdays at 8pm (UK) or Mondays at 10/9C (US) to catch the latest episode.

Enjoy the issue!

Jackie **Jackie Snowden**
Editor

"We are taken on a journey to the most spectacular parts of our unique planet"
One Strange Rock, page 68

Meet the team...

Charlie G
Production Editor
I love a good kick about, but I don't think I'd have had the guts to participate in a game of tlachtli. I'm all for sacrificing yourself for the team, but not literally!

Baljeet
Research Editor
From Cavendish 'weighing the world' to Fleming's accidental discovery of penicillin, discover more world-changing experiments from page 56.

Charlie E
Staff Writer
The release of Nat Geo's documentary *One Strange Rock* has given me a new appreciation of the weird little planet we inhabit. Find out more on page 68!

Scott
Staff Writer
Could scientists have found a way to help tackle the global problem of plastic pollution? Find out more in our Global Eye news section on page 10.

Duncan
Senior Art Editor
With the ability to destroy a planet, or cook it, the Sun's power deserves respect. Check out the feature on page 46 to find out how it threatens Earth on a daily basis!

Laurie
Studio Designer
I was amazed to learn how animals are outsmarting their prey with tools on page 76, like the crafty crocodiles that balance sticks on their snouts to entice nest-making birds!

FOLLOW US... How It Works magazine @HowItWorksmag

CONTENTS

TECHNOLOGY

20 Life in 2050
How tech will change the world in the not too distant future

28 Edible cutlery

28 Air purifiers

30 Inside the Apple HomePod

32 Get started with 3D printing

34 Bagpipes

TRANSPORT

36 The Trans-Siberian Railway
Discover the story behind the line that connected Asia to Europe

40 International waters

40 World's busiest station

41 The invention of tarmac

42 Airbus Beluga

SPACE

46 Space weather
Find out how and why we forecast solar storms

52 Heroes of: Robert Lawrence

54 Ultraluminous X-ray sources

54 Jupiter's cyclones

55 The Trappist-1 system

SCIENCE

56 Legendary science experiments
The amazing breakthroughs that changed our understanding of the world around us forever

64 What makes hair straight, wavy or curly?

64 Why our ears pop

65 What's in a name?

67 How dialysis works

ENVIRONMENT

68 One Strange Rock
Behind the scenes of the groundbreaking new series

76 How birds breathe

76 Creative creatures

77 Cotton: from field to fabric

HISTORY

78 Inside Hampton Court Palace
Take a tour of Henry VIII's favourite residence

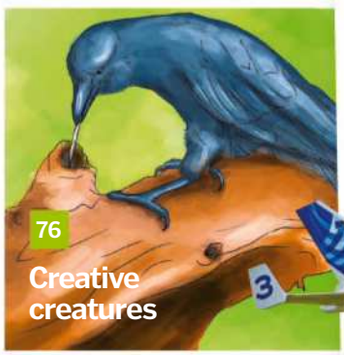
81 The Gompertz Law

81 Malta's Hypogeum

82 Women's suffrage

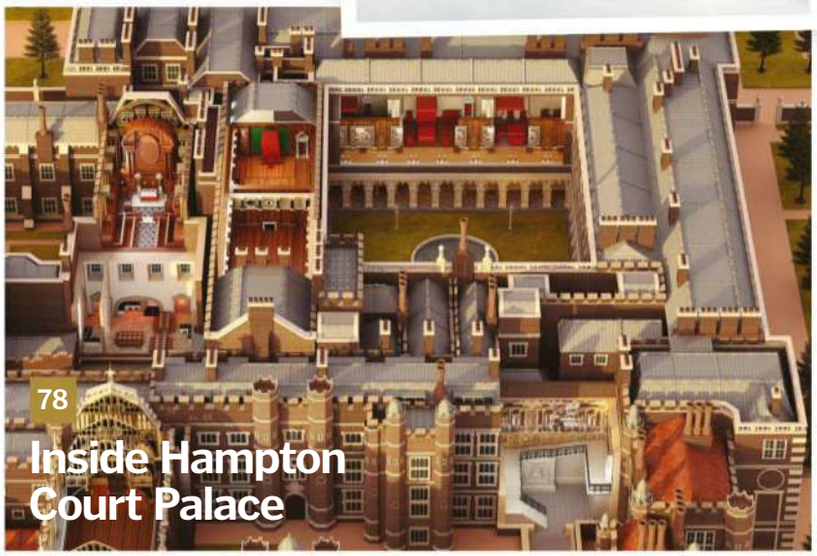
83 How to play tlachtli

46 Space weather



76 Creative creatures

42 Airbus Beluga



78 Inside Hampton Court Palace

MEET THIS ISSUE'S EXPERTS...

Alex Franklin-Cheung
Alex has worked at CERN in Geneva, London's Science Museum and the Institute of Physics.

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.

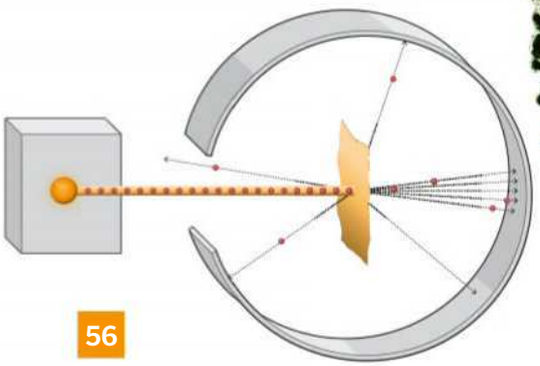
Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact, and Henry VIII to honey badgers.

Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.

Katy Sheen
Genetics graduate Katy works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

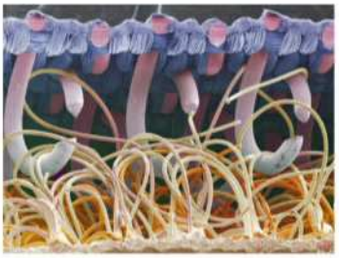
Lee Cavendish
Avid stargazer Lee writes for our sister magazine, **All About Space**, and has a degree in observational astronomy.



56
Legendary science experiments

68
Behind the scenes of One Strange Rock

REGULARS



06 Global eye
Science and tech stories from around the world

18 Wish list
The gadgets, games and apps we've got our eyes on

84 Strategy guide
The tactics of *Splendor* revealed

86 Brain dump
Your questions answered

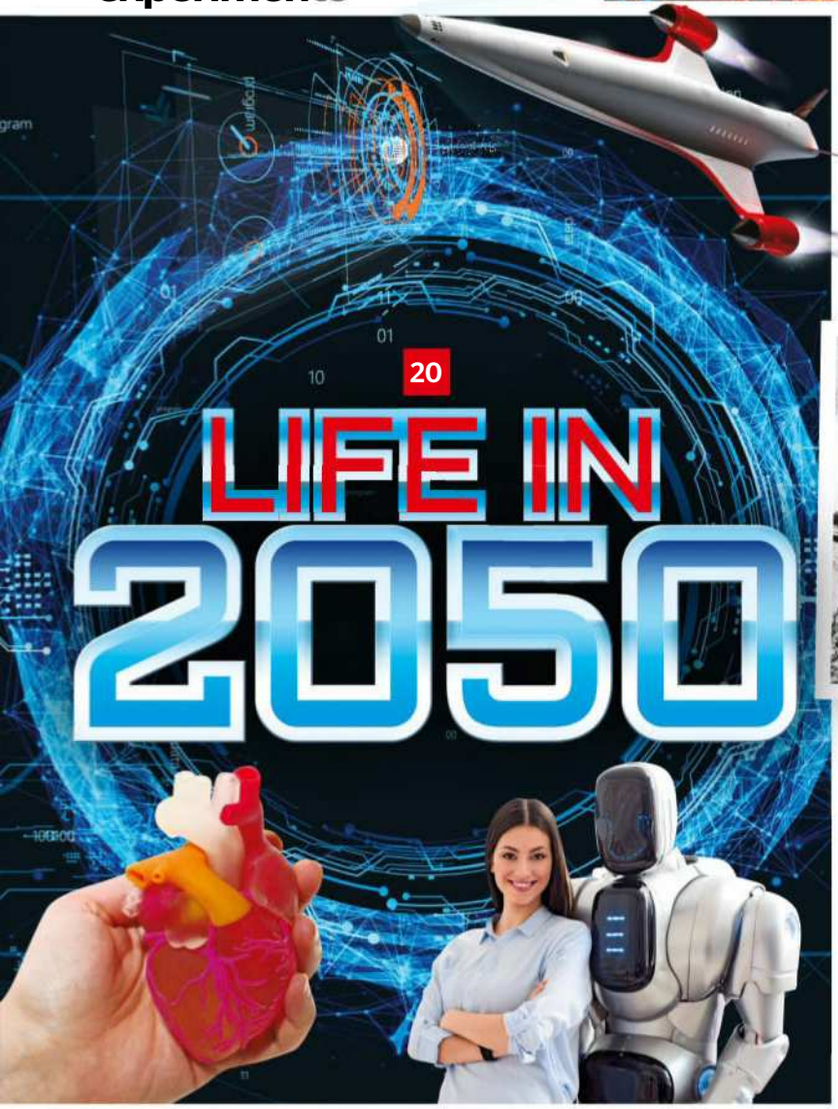
90 Book reviews
Check out the latest releases for inquisitive minds

92 Brain gym
Give your brain a workout with our puzzle pages

94 How to...
Make mini gymnasts and build a stomp rocket

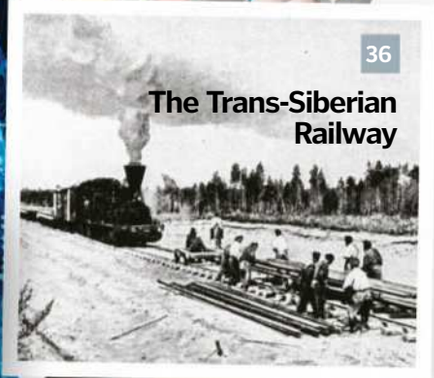
96 Letters
Our readers have their say on all things science and tech

98 Fast facts
Amazing trivia that will blow your mind



20
LIFE IN 2050

34
Bagpipes



36
The Trans-Siberian Railway

54
Jupiter's cyclones

Stephen Ashby
Stephen has been a write and editor for over seven years. He is endlessly intrigued by technology and Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for *All About History* and *History Of War*.

Tim Williamson
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.

Tom Lean
Tom is a historian of science at the British Library, working on oral history projects. His first book, *Electronic Dreams* was published in 2016.

Sakura blossoms come early

Each spring, the cherry tree (sakura) blossoms of Japan attract hundreds of thousands of visitors. Normally, the Tokyo trees bloom around the start of April, but this year the pale pink petals appeared in late March. These trees only bloom for a few days; there is even a specific forecasting service to track the blooms as they sweep across the country from south to north.

© Getty/KAZUHIRO NOGI

Extreme close-up

This false-colour SEM image shows a Velcro fastener at 15x magnification. The upper sheet contains hooks, visible in pink-purple, while the lower sheet contains loops, shown in pale yellow-orange. Pressing the two sheets together causes the hooks to attach to the loops, providing a grip that is both secure yet can be easily unfastened by peeling the sheets apart.

SCIENCE

Modified enzyme can eat plastic

Could this new discovery help solve our global plastic problem?

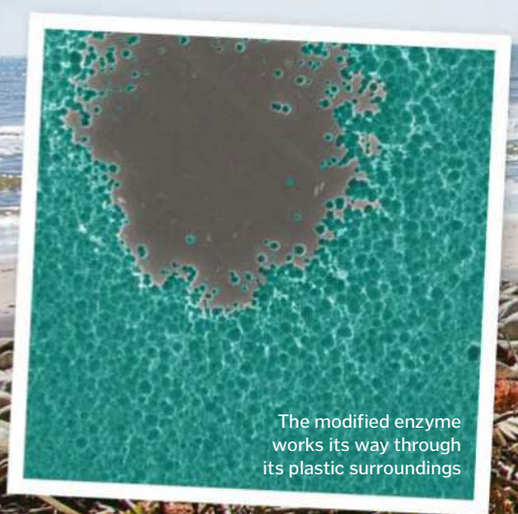
Scientists from the University of Portsmouth, UK, and the US Department of Energy's National Renewable Energy Laboratory have engineered an enzyme that can digest some of the most common and polluting plastics.

Since its rise in popularity in the 1950s, we have produced about 8.3 billion metric tons of plastic. Polyethene terephthalate (PET) is just one of many plastics and takes hundreds of years to degrade, meaning this enzyme could be the answer to a major environmental problem. The enzyme, known as PETase, was recently discovered to naturally digest PET. While testing and 3D modelling the enzyme, the team unintentionally engineered the PETase to break down the plastic at a much faster rate than it would naturally.

"Serendipity often plays a significant role in fundamental scientific research, and our discovery here is no exception," said Professor McGeehan, director of the Institute of Biological and Biomedical Sciences at Portsmouth, in a press release.

Having set out to determine the structure of the enzyme, the team modified the amino acids in its active site, and this change resulted in improved PET degradation.

"Although the improvement is modest, this unanticipated discovery suggests that there is room to further improve these enzymes, moving us closer to a recycling solution for the ever-growing mountain of discarded plastics, " McGeehan concludes. The team is now working to further reduce the time taken to break down plastic for use in industry.



The modified enzyme works its way through its plastic surroundings

Of the 8.3 billion metric tons of plastic produced so far, 6.3 billion has become plastic waste

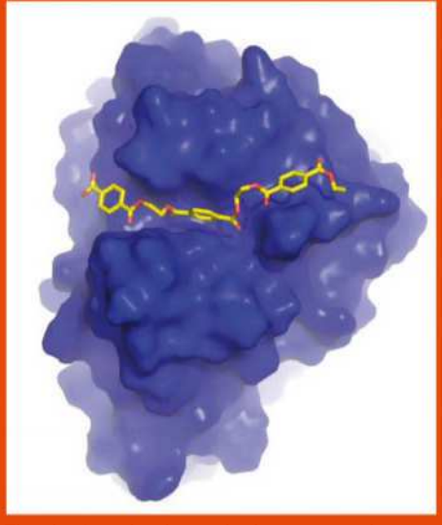
Viewing the plastic-eating enzyme

In order to view PETase at a molecular level, the team of scientists worked with the Diamond Light Source (DLS), the UK's synchrotron science facility.

Acting as a giant microscope, the synchrotron accelerates electrons to give off light 10 billion times brighter than the Sun, then beams that light to different laboratories. Having collected a large sample of the PETase, it was then crystallised and subjected to X-ray crystallography at DLS. This process uses the diffraction of X-ray beams to calculate the position of each atom and form a 3D model of the enzyme molecule.

Professor McGeehan said, "The Diamond Light Source recently created one of the most advanced X-ray beamlines in the world, and having access to this facility allowed us to see the 3D atomic structure of PETase in incredible detail.

"Being able to see the inner workings of this biological catalyst provided us with the blueprints to engineer a faster and more efficient enzyme."



The plastic molecules are broken apart as they pass through the active site of the PETase

ENVIRONMENT

Magnetic fields predict loggerhead turtle's genes

These magnificent sea turtles have a secret navigation system

Research from the University of North Carolina at Chapel Hill, US, published in *Current Biology*, has revealed vital insights that could help improve loggerhead sea turtle conservation.

The project, led by biologists Kenneth J Lohmann and J Roger Brothers, has found that species nesting on beaches with similar magnetic fields are genetically similar to one another. Loggerheads swim all around the world, but this research suggests that the groups that are most genetically similar are those nesting within similar magnetic fields, regardless of how close the beaches are to one another or how similar the environment.

Previous research has shown that when it comes to laying their own eggs, female loggerheads use magnetic fields to find their way back to the place they hatched themselves. However, it has now been demonstrated that turtles can mistakenly nest at different beaches if they have a similar magnetic field 'signature', even if that beach is physically far away from their intended destination. The research has provided new insights into their long-distance migration and navigation, and suggests that conservation efforts should take into account human activity that could interfere with magnetic fields, such as buildings and electrical infrastructure.

Kenneth Lohmann, professor of biology in the College of Arts and Sciences at UNC-Chapel Hill, said, "This is an important new insight into how sea turtles navigate during their long-distance migrations. It might have important applications for the conservation of sea turtles, and other migratory animals such as salmon, sharks and certain birds."

Baby loggerhead sea turtles head straight for the ocean as soon as they hatch

Loggerhead navigation

Loggerhead turtles are able to sense the Earth's magnetic field lines. They use this ability to identify their coastline among hundreds of others, each one with its own magnetic field signature. It means they are able to travel hundreds of miles into the ocean yet always navigate back home without using landmarks – just their instinctive ability to recognise the magnetic patterns. These patterns naturally shift over time, but the turtles are able to keep up with these challenges and slightly shift their nesting sites in accordance with the change.

Loggerhead turtles can be found in the Atlantic, Indian, and Pacific oceans

This visible light view of the Lagoon Nebula shows glowing oxygen gas (blue), glowing nitrogen (red) and the light from Herschel 36 (yellow)

SPACE

NASA's Hubble Space Telescope celebrates its 28th anniversary

The orbiting observatory has marked the occasion with a stunning image of the Lagoon Nebula

NASA's iconic telescope has spent the last 28 years photographing the beauty of our universe. To celebrate the anniversary of its launch, Hubble has captured an image of a giant young star called Herschel 36, which is 200,000-times brighter than our Sun. The star is blasting out powerful ultraviolet radiation and stellar winds, pushing out the surrounding dust clouds to create these dramatic patterns. The Lagoon Nebula is 4,000 lightyears away and can be spotted with binoculars, but Hubble has captured the activity of this distant display in incredible detail.

TECHNOLOGY

Spider silk could revolutionise regenerative medicine

The biodegradable material can be used to help repair load-bearing bones

Broken load-bearing bones may require metal plates to help them heal correctly, often requiring a long and painful recovery. In a potentially life-changing breakthrough, researchers from the University of Connecticut in the US, have created a biodegradable spider-silk composite material that could help improve the healing process.

The new composite is a flexible alternative, meaning patients in recovery can still have a wide range of movement while the injury heals. The researchers created the new material – consisting of long fibres of silk and polylactic acid – after focusing research on a protein that gives spider webs their toughness, strength and flexibility.

The material would break down once the bone is fixed. Traditional methods often require further surgery to remove metal plate implants

HISTORY

New species of ancient whale found

Palaeontologists have uncovered a new species from samples excavated 30 years ago

Palaeontologists from the University of Otago, New Zealand, analysed samples of whale fossils taken from Hakataramea Valley back in 1988. By examining the skulls and associated bones, the team established the new genus and species, assigning it the name of *Toipahautea waitaki*.

"This newly named whale lived about 27.5 million years ago. It's about as old a common ancestor as we have for the living baleen whales like the minke whales and the right whales," said Professor Fordyce, who worked on the project.

The ancient species was relatively small, with a body around 5m long

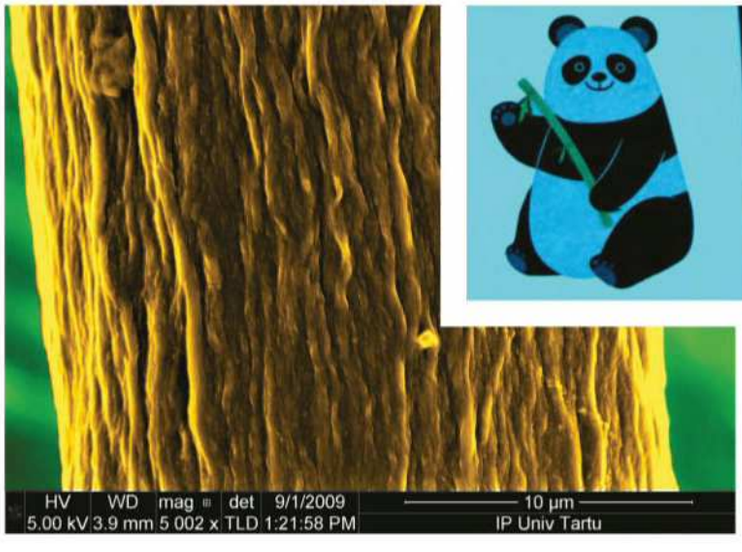
TECHNOLOGY

Rechargeable yarn creates wearable battery pack

New carbon-fibre batteries can be woven into clothes to charge tech

A group of researchers have engineered an innovative battery to charge wearable technology. As the popularity of wearable devices, continues to grow, the demand for new charging methods also increases. The new batteries are made from carbon nanotube fibres that are twisted into yarn and coated with metal and sealed with an ion-filled resin. The battery is waterproof, flexible and still works after being cut. The team demonstrated the battery's capability and viability by using it to illuminate a belt containing 100 LED lights and an electroluminescent panel.

In a demonstration, the woven battery yarn was used to power this electroluminescent panel



Carbon nanotube fibres can be used to strengthen many different materials

HISTORY

Man's best friend for 10,000 years

Our relationship with our canine companions goes way back

We have long known that dogs have lived, hunted and migrated across the world alongside us for thousands of years, but now the oldest remains of dogs in the Americas have been discovered.

Three canine companions were found at two ancient burial sites – Koster and Stilwell II – in Illinois. It is thought that the skeletons are around 10,000 years old, making them the oldest known dog skeletons in the Americas. Their estimated age had previously been determined based on radiocarbon analysis of wood found in the graves, but the latest research shows they are 1,500 years older than previously thought.

The bones have no injuries or incisions, suggesting they were not killed by humans. Instead, it is likely they died from natural causes before their burial. Unlike today's breeds, the excavation team found that the lower jaws and teeth of the dog from Stilwell II and one of the Koster dogs displayed traits similar to modern-day wolves, while the other Koster dog showed similarities to the present-day coyote.

New genetic studies on the remains of the Illinois dogs has placed them in the same lineage of the canines that initially populated North America. Genetic analysis of dogs excavated from over 20 sites, between 10,000 and 800 years old, suggest that the Illinois dogs shared a common ancestor around 15,000 years ago, after diverging from a closely related group of Siberian dogs 1,000 years beforehand.

The origin of domestic dogs

Researchers believe that the first dogs were domesticated at least 15,000 years ago, with some estimations going as far back as 20,000–40,000 years ago.

One theory is that people started taking in wolf pups from the packs that were scavenging from our ancestors. Socialising with the puppies while they were young meant they would grow up to see the human as their pack leader. It's thought that a symbiotic relationship between dogs and humans started to evolve and man and wolf would hunt together. Over time, the dogs lost their wild wolf ferocity and became the tame companions we know and love today.

Some research suggests that humans first domesticated dogs as long as 40,000 years ago

Researchers believe that ancient dogs looked more like present-day dingos than our modern pets

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

1 99.75% of coffee cups aren't recycled

Billions of takeaway coffee cups are used each year, but only a shockingly small proportion of them are properly recycled. These cups contain an inner lining made of a plastic and paper mix, which helps to insulate the cup and keep it leakproof. However, this lining makes them very difficult to recycle, and in the UK only a handful of specialist plants are currently able to process them properly. While efforts are being made to develop more easily recycled cups, many coffee chains encourage customers to bring their own reusable travel mugs.

2 Smartphone addiction can increase loneliness and anxiety

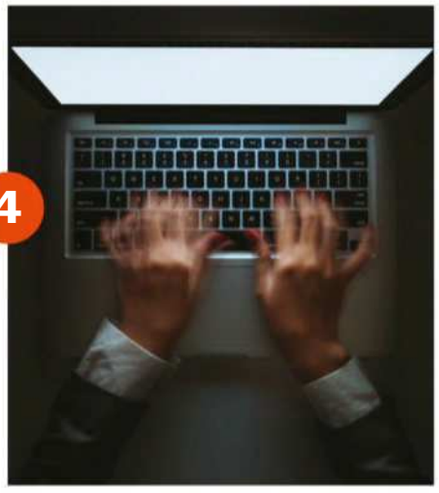
You would assume that smartphones would improve our social lives, but scientists from San Francisco State University, US, have found that overuse of smartphones can actually have a negative impact on our social connections. They also discovered those addicted to social media have an increased risk of suffering from anxiety, depression and loneliness.

3 Canada has alien lakes

Two subglacial lakes in the Canadian Arctic may be similar to those expected to exist beneath the icy surface of Jupiter's moon Europa. The recently discovered lakes are beneath 550–750 metres of ice and would need to have high levels of salt to remain liquid at a temperature no higher than –10.5 degrees Celsius.

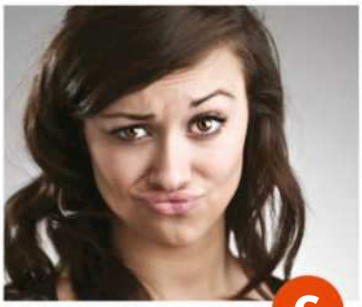
4 Faster typists make fewer mistakes

Researchers from Aalto University in Finland and the University of Cambridge, UK, studied the speeds of 168,000 typists from over 200 countries. They found the fastest typists made fewer errors and used rollover typing, when the next key is pressed before the previous key is released.



5 Too much sitting is bad for your brain

In a preliminary study of 35 adults between the ages of 45–75, scientists from UCLA, US, found that those who spent more hours sitting tended to have a thinner medial temporal lobe, which may be linked to cognitive decline or even dementia.

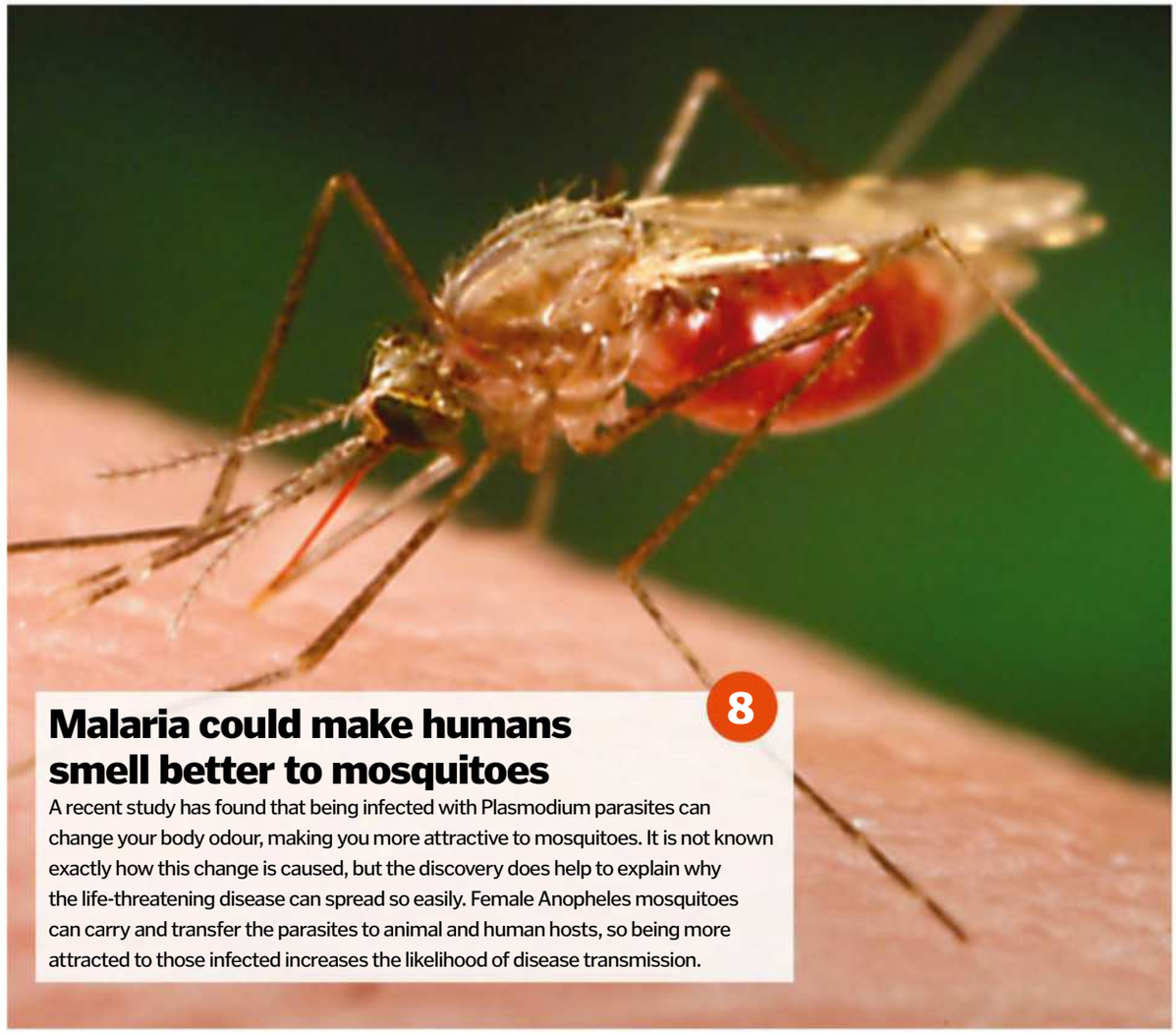


6 Agile brows helped us evolve

Scientists from the University of York, UK, have proposed that having mobile eyebrows improved the communication skills of early humans. Other Hominin species had much larger brow ridges, while modern humans evolved smoother foreheads with more visible eyebrows. It's thought this helped us form larger groups as we became able to express subtle emotions.

7 Proteins can cure cavities

A new dental product developed by researchers from the University of Washington, US, could revolutionise the way cavities are treated. They have developed a biogenic formulation that uses peptides to rebuild the enamel on the tooth, mimicking the natural tooth-forming process.

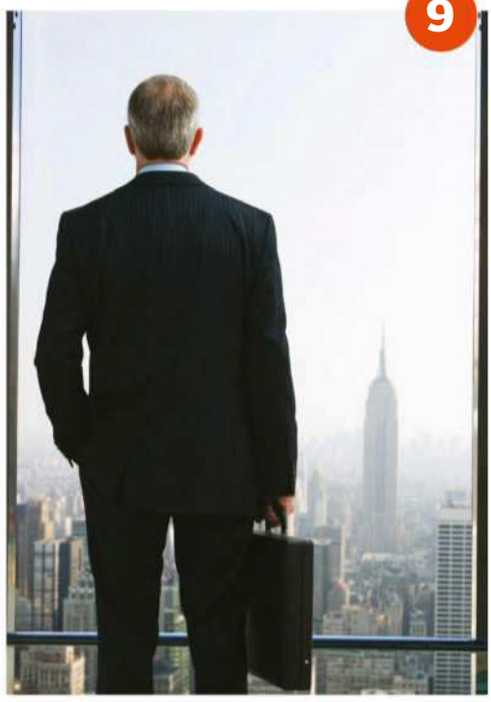


8 Malaria could make humans smell better to mosquitoes

A recent study has found that being infected with Plasmodium parasites can change your body odour, making you more attractive to mosquitoes. It is not known exactly how this change is caused, but the discovery does help to explain why the life-threatening disease can spread so easily. Female Anopheles mosquitoes can carry and transfer the parasites to animal and human hosts, so being more attracted to those infected increases the likelihood of disease transmission.

Office elevation can affect your decisions

Researchers from Miami University, US, have revealed that investors whose offices are on a higher floor are more likely to take financial risks. The team analysed data from over 3,000 hedge funds and found a small but significant link between a fund's volatility (how risky it is) and the floor it is situated on. It is thought that being higher up gives a subconscious boost to your sense of power, which could lead people to overlook risks.



9

10 Graphene spikes can kill bacteria

A team from Chalmers University of Technology in Sweden have discovered that a tiny layer of graphene flakes applied to implants could help prevent infections during surgeries. Bacterial infections during implant operations, such as hip replacements, are always a risk and can result in the implant needing to be removed. The researchers found that the graphene flakes acted like spikes, slicing apart and killing the bacteria so infection couldn't take hold.

WISH LIST

The latest must-have technology

Augmented reality Iron Man mask

■ Price: £46.99 / $49.99 / www.smythstoys.com

This augmented reality movie-inspired Iron Man mask and gauntlet are aimed at children aged eight years and over – but the adjustable head strap meant that our team didn't have to miss out on the fun! Just find somewhere with space to play and put your smartphone into the visor after downloading the Hero Vision app and you're ready to suit up. Place the augmented reality markers in a room and bring the gauntlet up towards your face so the app can recognise the codes and start tracking its movement. The aim of the game is to use your blaster to defeat the enemies over ten levels before fighting Thanos.

The Voyager Golden Record

■ Price: $98 / approx £70 / www.ozmarecords.com

Launched in 1977, the Voyager 1 and 2 spacecraft carried an ambitious message to extraterrestrial life – we are here, this is our world, and this is who we are. The phonograph records contain instructions, sounds and images to tell our story, including music (from Chuck Berry to Beethoven), greetings in 55 different languages and sounds from nature, such as whale song and the crack of thunder.

These high-quality near-replicas from Ozma Records are a set of three translucent, gold, 140-gram vinyl LPs in polylined paper sleeves and come with a full-colour, 96-page softcover book, digital audio download and a lithograph of the iconic Voyager Golden Record cover. The magnificent attention to detail means that, while we might not be able to jet into space anytime soon, at least we can kick back to the sounds of Earth and dream of all of the aliens that might one day discover our species' intergalactic time capsule.

iconBIT Smart Kick Scooter

■ Price: £499 / approx. $690 / www.iconbit.com

In a rush to get to work or your favourite hangout? The iconBIT Smart Kick Scooter is a quick, easy and fun way to get from A to B. This lightweight carbon-fibre scooter retains all the features you'd expect of a traditional folding scooter while including a 350-watt motor and power braking. Sleek and stylish in its design, its folding ability means you can flatten it in a flash.

Accompanied by an onboard computer display, the driver is able to select one of three preset speeds, which top out at 25 kilometres per hour. This scooter allows the rider to travel for between three to four hours before needing to recharge, making it perfect for a daily commute or afternoon play.

ZIIIRO Mercury Watch

■ Price: **$199 / approx. £145 / www.ziiiro.com**

We love the unique and innovative way that the ZIIIRO Mercury watch displays time. The larger of the swirling discs of vibrant colour represents the current hour, while the thinner one shows the minutes. The clock face has a futuristic feel, with mesmerising gradient movement that displays the passing of time.

Available in a variety of colours, from ocean blues to bright oranges and reds, the Mercury watch is crafted from stainless steel and hardened mineral crystal and features Japanese Miyota 1L-26 Quartz Movement with a two-pole stepping motor that provides an incredible accuracy of +/-20 seconds per month. Other watches by ZIIIRO include playful and bold concepts, such as the ORBIT, which shows the time using dots that orbit the clock face.

ROXI by Electric Jukebox

■ Price: **£199 / approx. $280 / www.electricjukebox.com**

An independent study has revealed that 89 per cent of parents think music could bring their family closer together. This is something music entertainment brand Electric Jukebox is helping to achieve. Combining the popularity of music streaming with technology to create a party atmosphere, ROXI is an entertainment system with built-in fun for all the family. Users can stream music from their favourite artists through their televisions and access millions of tracks from all genres. What makes ROXI unique is its 'Sing with the Stars' feature, with the voice search controller doubling as a karaoke microphone. Jam-packed with extra features, the ROXI includes a music trivia game called *Name that Tune* and a tranquil 'Sound Machine' for gentle background music. This compact all-in-one ROXI hub only needs a Wi-Fi connection to get the party started.

Sphero Mini

■ Price: **£49.99 / $49.99 / www.sphero.com**

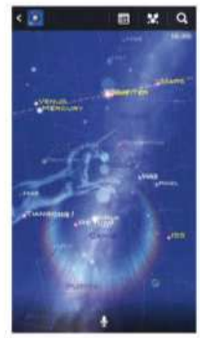
They say great things come in small packages, and the Sphero Mini is no exception. Using the accompanying app, you can use this tiny robot (about the size of a ping pong ball) to drive around and play games. With the Face Drive feature you can even control the ball using different facial expressions! But it's more than just a fun toy: you can learn to code too. Using the Sphero Edu app, you can develop your JavaScript skills by programming the Mini to perform different actions.

APPS & GAMES

Star Chart Infinite

■ Developer: **Escapist Games Limited**

■ Price: **£2.99-£4.99 / $4.99 / iOS / Android**



Have you ever gazed up at the sky at night and wondered which stars and constellations you are watching? This app works like a virtual planetarium. By integrating GPS technology and an accurate 3D map of the universe, this app can show you the location of all of the stars and planets visible from Earth.

Collins Bird Guide

■ Developer: **NatureGuides Limited**

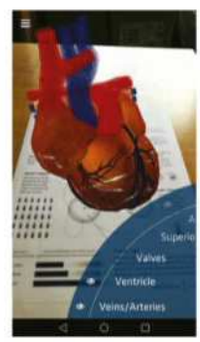
■ Price: **£12.99-£14-99 / $14.99 / iOS / Android**

This app is one of the more expensive in our Wish List, but it is worth it for the sheer quantity and quality of the information packed into the guide. The world-class illustrations are accompanied by over 750 identification songs and calls, which combine with detailed text on habitats, ranges and identification techniques to make this a fantastic addition to your smartphone if you are interested in bird life.

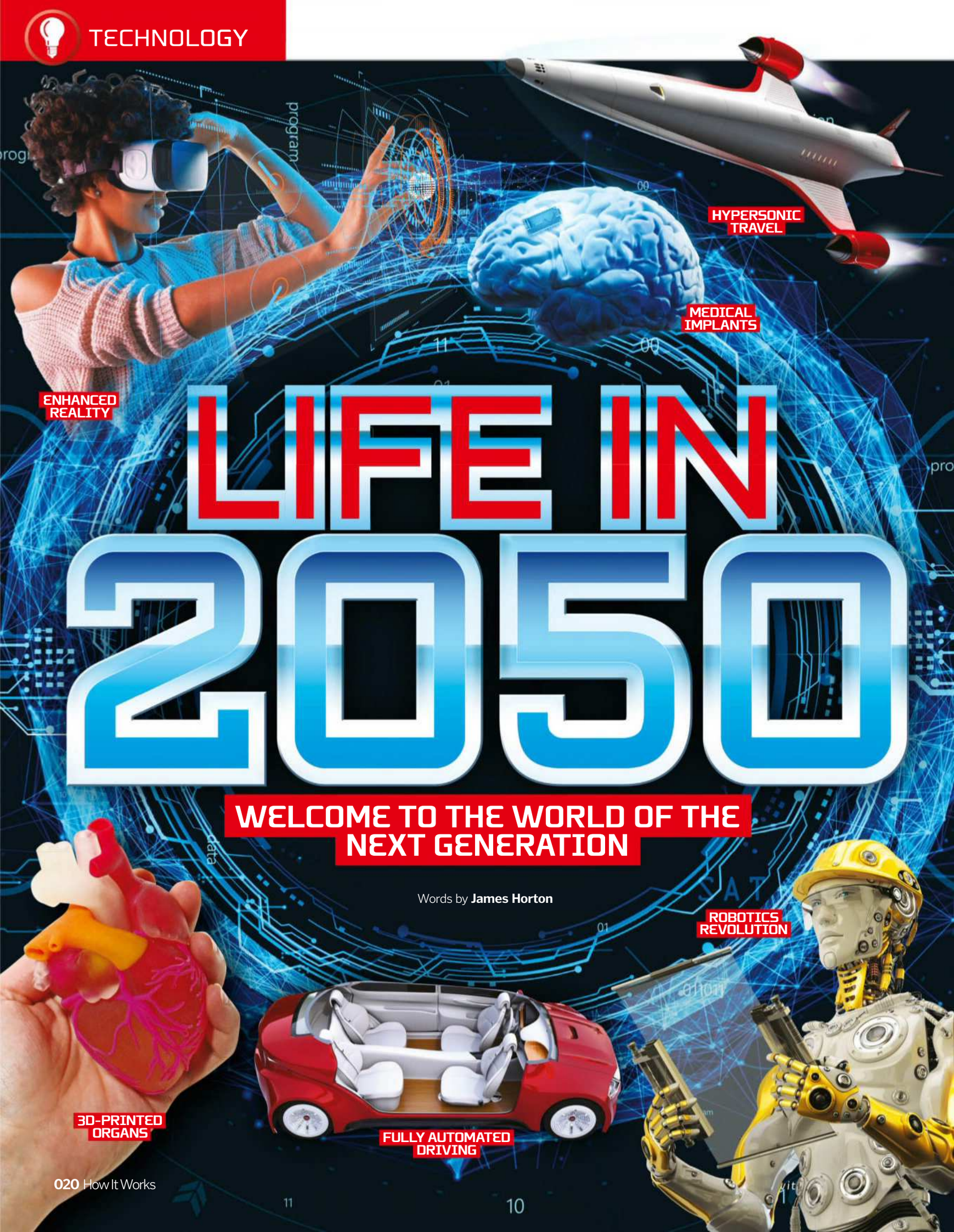
Anatomy 4D

■ Developer: **DAQRI Education**

■ Price: **Free / Android**



If you want to learn about the human body, in particular the heart, then this is the app for you. Anatomy 4D takes a simple infographic printout and transforms it into a 3D model for an augmented reality experience. This is an excellent app, providing a new way to discover the human body.



Words by **James Horton**

Sprawling, eco-friendly megacities, a global population exceeding 9.8 billion, and far-reaching inventions that marry biology and technology all lay ahead of us. Today's world is one filled with ideas, innovation and imagination, making us perfectly poised to speculate on what the world will become in just over three decades.

It may seem dangerous to cast our eyes so far ahead, across decades of exponential progress. But in today's research we find the seeds of the era-defining technologies that will come to be. In the 1950s, Alan Turing considered the 'ghost in the machine' and challenged his contemporaries to consider whether we could truly create intelligent – if not sentient – machines. Now, with deep neural networks and other artificial intelligence approaches we find ourselves edging ever closer to an idea first posed over 60 years ago. Turing's vision has almost been realised, and within this feature we will uncover analogous ideas that may grow, just as Turing's vision did, into technologies that will bring similar disruption to the world of 2050.

MAKING NEW STRIDES

As the collective pool of human knowledge continues to expand, we will increasingly see branches of research broaden their perspective and bleed into different areas of investigation. Such fusions of science and technology will play a pivotal role in the years to come. For example, forensics may start incorporating the staggeringly broad applicability of data science. Researchers at Oxford University have for the first time uncovered genetic variations that are strongly associated with particular facial features. As we move forward and others

> *"In today's research we find the seeds of the era-defining technologies that will come to be"*

inevitably expand on this novel finding – and the link between a person's unique genetic code and their facial features is revealed – a wanted person's DNA will suddenly reveal much more than just a simple match on a known criminal database. Amazingly, police officers in 2050 will likely be able to create an accurate facial model from a mere drop of saliva or a single strand of hair. Then, with the help of smart computer systems, they will be able to scour the area with drones and locate their target.

At the centre of these cross-disciplinary technological marvels, however, will lie

Tomorrow's cities will be home to vertical farms, enhanced greenery and a multitude of new buildings

Brain-computer interfaces will allow us to control tomorrow's technology by thought alone

Delivery services, provided by autonomous drones, will be faster and cheaper than today's options

brain-computer interfaces similar to the kind being developed by Elon Musk's Neuralink. This intriguing company endeavours to create a neural mesh capable of directly linking to the cloud, forming a bridge between our thoughts and the electronic world around us. Musk rightly points to our current reliance on smartphones – and namely how we loathe to be without them – as evidence that we're already bound to technology. But in 2050 this connection will have deepened to the extent that we will have access to implants that form a neural interface around the outside of our brains.

For those equipped with such technology, information from the web will be directly delivered to their thoughts on a moment's notice (much to the chagrin of pub quiz runners); electronic devices will be controlled just by thought; and people will be able to enjoy 'consensual telepathy'. This may seem the product of sorcery, but in 2050, when technology will be even more integral and abundant than it is today, interfaces that permit easier interactions with our creations will become hugely advantageous. The medical applications of this technology are also worthy of mention, as those with brain and other central nervous system injuries will be able to utilise this tech to circumvent severed connections via the cloud. As a result, communications between the brain and limb will be restored, and those who are severely paralysed will be able to more easily interact with the outside world.

> *"Most meat will be lab grown rather than traditionally farmed"*

The places we inhabit will also have transformed by 2050. For those who live in rural areas, more land will become available for biodiversity to prosper in once more as agricultural land will be stripped back. With a swelling population we may expect farming land demand to grow rather than dwindle, but many meats will be available in the form of lab-grown varieties, and cities will employ vertical farming to generate food supplies.

Off-world mining

Many nations throughout the world are committed to cutting down their carbon footprint in the coming decades, with the hope that by 2050 it will be significantly reduced. A vital part of this vision includes an increased reliance on batteries and other electronics, which will be key for renewable energies and emission-free electric cars. But mining enough precious metals to meet the ever-growing demand represents a serious hurdle.

One undesirable answer to this problem is to employ deep-sea mining that targets hydrothermal vents. These are known to be rich in metal deposits but are truly remarkable oases of life (and may even be where life began), so a better alternative is needed. This will come in the form of off-world mining on local asteroids as well as our closest companion – the Moon.

Mining the Moon holds great promise thanks to its deposits of helium-3, an isotope ejected from the Sun that will eventually be used as fuel in nuclear fusion reactors. With robot workers and giant 3D printers to create infrastructure, off-world mining will be able to provide us with a continuous supply of precious and much-needed resources.

Mining precious metals off-world will be integral for the future production of electronics

YOUR FUTURE LIFE

Fill the shoes of tomorrow's citizen and uncover what an average day will be like in 2050

19:30pm
To help reduce harmful emissions and intensive farming, most meat will be lab grown rather than traditionally farmed. This will vastly reduce waste as well as the need for large areas of pasture.

9:00am
Most labour and administrative jobs will be completed autonomously, which means many members of the adult population will receive Universal Income and enjoy complete freedom of their time.

17:30pm
Virtual reality headsets, haptic-feedback suits and blistering connection speeds will mean we'll be able to game inside immersive and expansive digital worlds.

9:30am
Advancements in AI and quantum computing will allow us to create truly powerful artificial brains, which will, in part, act as intelligent virtual assistants.

17:00pm
Hyperloop vehicles, housed in cylindrical tunnels underground and above our heads, will travel at nearly 1,000kph to get us home.

10:00am
Battery-powered, self-driving cars will be readily available as an affordable, safe and eco-friendly taxi service whenever we need it.

15:00pm
Adverts will interact with our augmented reality headsets to create 3D holograms featuring carefully selected products.

11:45am
Increased global trade will lead to a cryptocurrency taking the lead as a universal digital currency to pay for whatever, wherever we are.

14:30pm
Thanks to Universal Income there will be ample opportunity to book a holiday. Upgrade your ticket to a hypersonic flight and you'll be able to reach anywhere on Earth in just a few hours.

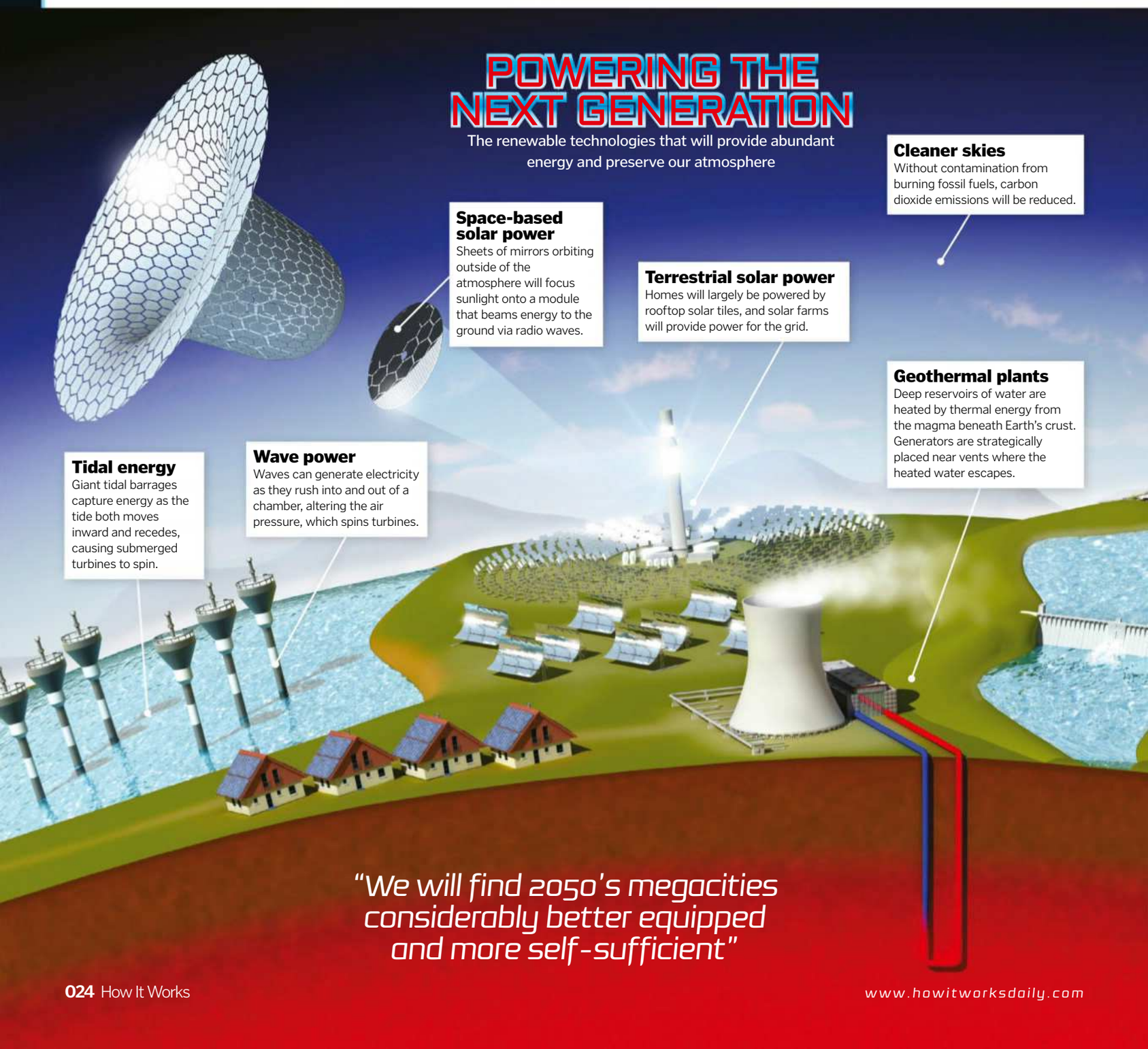
12:00pm
Travelling to meetings will be unnecessary thanks to high-definition augmented reality headsets, which will enable interaction in 3D space.

Vertical farming, where tiers of crops are stacked atop one another, may take up residence as great glass skyscrapers in tomorrow's cities. There, they will be able to grow nutritious crops including tomatoes, lettuces and greens, as well providing greenery to the urban landscape. Smaller-scale vertical farms may also be affixed to the sides of older buildings, providing cleaner air and extra food sources. It has been estimated that the largest vertical farm structures could provide food for up to 50,000 people. Food loss from transport and storage will be eradicated, fewer pesticides would be needed thanks to the segregated environments, and crops could be grown throughout the year. And, as an added bonus, sealed vertical farms would naturally recycle their own water supply, making the process even more economical.

As a whole, we will find 2050's megacities considerably better equipped and more self-sufficient than those of today. Bioengineered microorganisms will help to clean the water supply, lowering the energy expenditure required for water processing, and we may even save power in the evenings as street lights are replaced by glowing trees. These will be products of technologies that will build upon the success of MIT scientists, who at the end of 2017 successfully engineered leaves using nanoparticles that glowed vibrantly under the plant's own power. Providing both light and beauty to the city, the glowing trees will help transform our metropolises from concrete jungles into otherworldly visual spectacles.

THE RISE OF AUTOMATION

Some of the ideas we have visited thus far in this feature have been likely, some a little more speculative and others wishful, but one thing that companies the world over are barrelling toward is autonomous systems. A world dominated by self-acting machines seems to be



"We will find 2050's megacities considerably better equipped and more self-sufficient"

ECO-FRIENDLY IN 2050

Welcome to a future built on renewable and sustainable energy sources

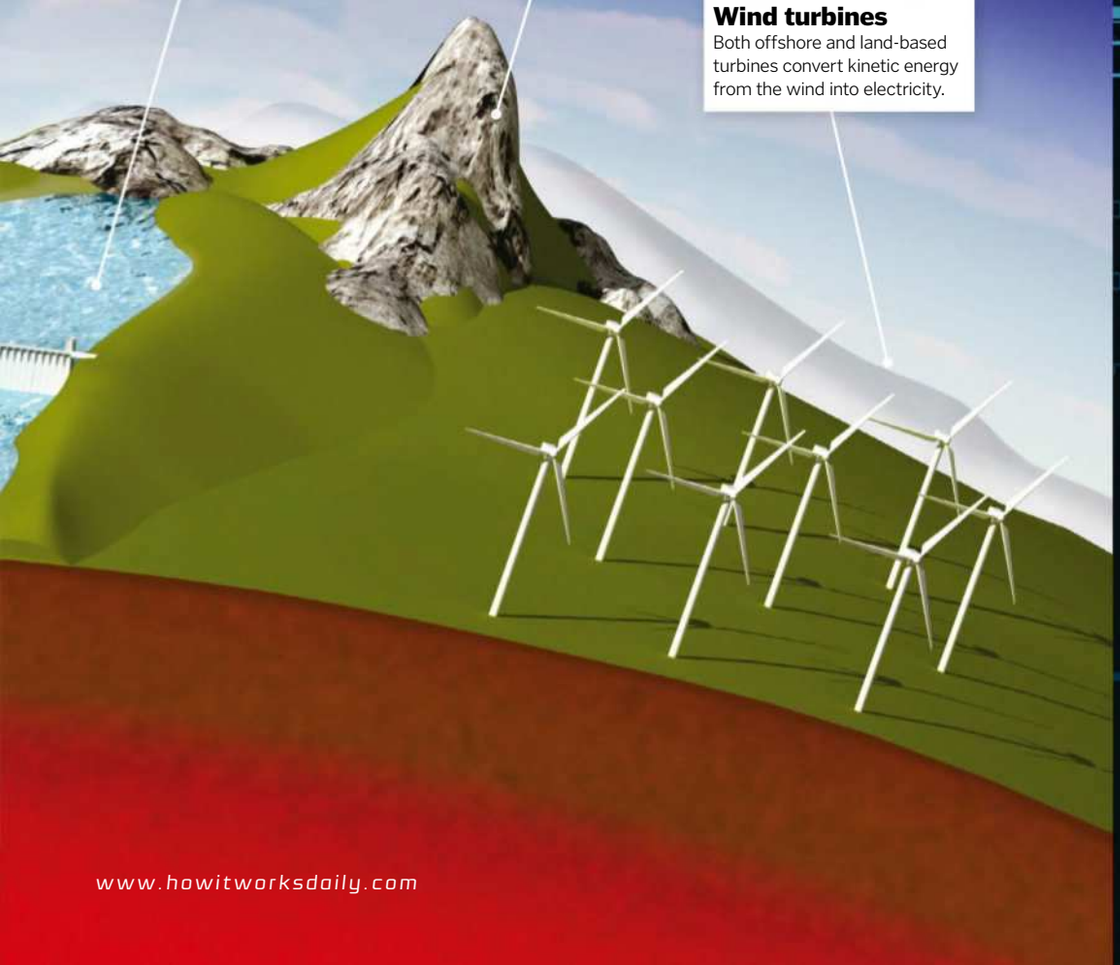
It is hoped that self-driving cars will dramatically reduce road accidents

It is estimated that robots will replace around 800 million workers by 2030

Hydroelectric energy
Dams can serve a dual purpose of preventing flooding but also providing energy. As water flows through the intake it spins turbines to power generators.

Harnessing nature's energy
Every moment, radiation is ejected from the Sun, our planet spins and its molten core swirls. All of these phenomena release energy, which these technologies will capture.

Wind turbines
Both offshore and land-based turbines convert kinetic energy from the wind into electricity.



139
The number of countries that could be powered entirely by renewable energies in 2050

24 million
The net gain of jobs created for countries relying solely on renewable energy

2040
The year the UK plans to ban sales of vehicles powered by fossil fuels

42.5%
The estimated decrease in energy demand after we switch to efficient renewables

1.1 million tons
The estimated mass of helium-3 on the Moon's surface

48%
The predicted contribution of solar-power-based technologies to energy production in 2050

etched into our destiny, as every year we uncover greater possibilities and achieve new milestones, some of which have come a decade before their predicted time.

Fortunately, this won't lead to an ominous revolution of robots and their artificial intelligences, but rather an integration of autonomous systems into nearly every facet of our lives. They will become the tireless worker drones that gather, process and organise our data, clean our offices, deliver our parcels and so much more. If we look around us today we can see that this change has already begun. Stock brokers rely on algorithms to predict fluctuations in the stock market; Facebook programs dig through our internet cookies to learn the right advertisements to feed us; and fast food chains are replacing staff with burger-flipping robots.

There are a slew of reasons for this major cultural shift. Algorithms and robots will prove cheaper for companies, more efficient, and when handling data, simply far superior than any human counterpart. The only major hurdle left to overcome in the following years involves teaching machines how to perform a job optimally. But once they've learnt it, you can be certain that they'll be much more capable than their human predecessors.

So what does this mean for jobs? For some, it'll mean a much easier working life. Such beneficiaries will of course include most large business owners, but disciplines such as medicine - and the patients that they treat - will be bolstered by artificially intelligent support. A multitude of disease diagnoses, for instance, are still assessed by eye alone. This outdated approach has an element of subjectivity and is prone to error, but machines that have been trained on tens of thousands of images will be able to aid medical practitioners by accurately diagnosing diseased tissue.

Yet for many others careers, machinated workers will simply offer a favourable alternative to human employees. One study estimated that certain sectors could see up to 50 per cent of jobs being handed over to robots and AI by 2030, and we can be certain that the following two decades will see machines grow exponentially more capable, and many other careers will come under threat. Jobs that require empathy and creativity are currently believed to be immune to the incoming influx of automation, but can we be so confident that a machine won't be able to outperform a human in these areas by 2050?

Those vying for the remaining jobs, which will likely include policing, governing, teaching, researching and counselling, will face a fiercely competitive environment, especially as the global population is set to increase to nearly 10 billion by 2050. As a result, we may find ourselves in the era of Universal Income, where the governments of the world will provide pay to adults without them having to work. This way the economy keeps turning and the population becomes able to invest their time in whatever they please, free from the pressure of generating income. It would represent the greatest change in our daily lives for hundreds of years and pave the way for people to continue the phenomenal technological upward trend of the past 50 years.

Robot workers will free future populations from many manual tasks, including those in agriculture

Tunnels kept at near-vacuum pressures will house superfast vehicles known as hyperloops, which will transport future citizens around at 1000kph

Extended lifespans

An ageing population can be a fearful prospect for future generations due to the economic pressures of having to provide and care for a considerable portion of a country's citizens. But what if old didn't have to mean infirm; what if we could prevent the effects of ageing and keep people fitter and healthier for longer? A reality such as this one should be in effect by 2050 with the help of revolutionary regenerative technologies such as telomere extension.

Telomeres are essentially the 'caps' on the ends of our chromosomes, made up of long strings of basic genetic building blocks that are slightly shortened every time a cell divides. When the telomere is gone the cell can no longer properly replicate, and instead it dies. In a way, telomeres represent our natural lifespans, and with recent progress researchers have shown that extending telomeres with the help of proteins can restore cell division and prolong life. So for someone born in 2050, age-related issues including hair loss, compromised bone marrow and heightened cancer susceptibility will be a problem from another century.

Enzymes that sustain telomeres may offset many age-related diseases

TOMORROW'S MEDICAL MILESTONES

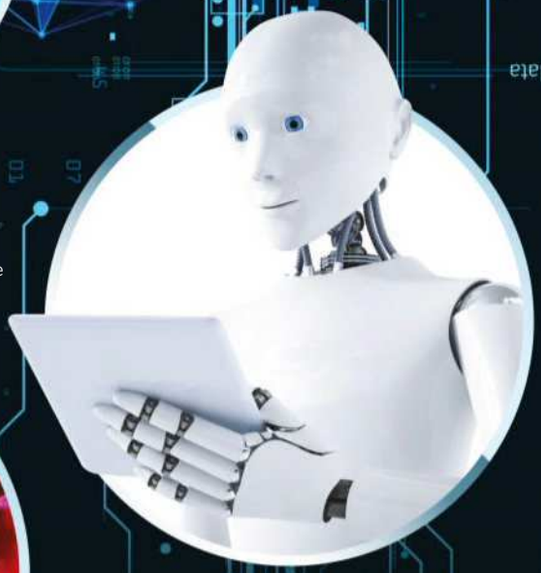
Discover the top innovations that will transform the future of healthcare

Monitoring your health 24/7

Through wearable gadgets and small implants, key health indicators such as blood pressure, heart rate, cholesterol levels and blood sugar will all be recorded and transmitted continuously, ensuring that help will be at hand as soon as you need it.

3D printed organs

With basic biological components as the building material, bioprinters will be able to create new organs from the bottom-up. Simpler organs such as skin, and even more complex systems such as livers and lungs, will free patients from relying on donors.



The AI doctor

After decades of training intelligent algorithms to recognise patterns and symptoms of disease, 2050's 'consultant computers' will be able to reliably and accurately diagnose almost any condition and recommend the best course of treatment.

Synthetic blood cells

Plastic 'smart particles' that can bolster the immune response by binding to invading cells, and carbon-based 'respirocytes' carrying 100 times more oxygen than red blood cells, means future generations will enjoy near-superhuman levels of defence and fitness.

"For someone born in 2050, age-related issues will be a problem from another century"

Advanced bionics

The future of exoskeletons and artificial limbs will rely upon improved robotics for increased synthetic limb acuity, as well as brain-bionic interfaces that wirelessly transmit electrical signals from the brain to an attached appendage, meaning it can be moved by thought alone.

Air purifiers

These devices use scientific principles to help you breathe easy


Air purifiers are used in the home and for industrial purposes, such as clean rooms

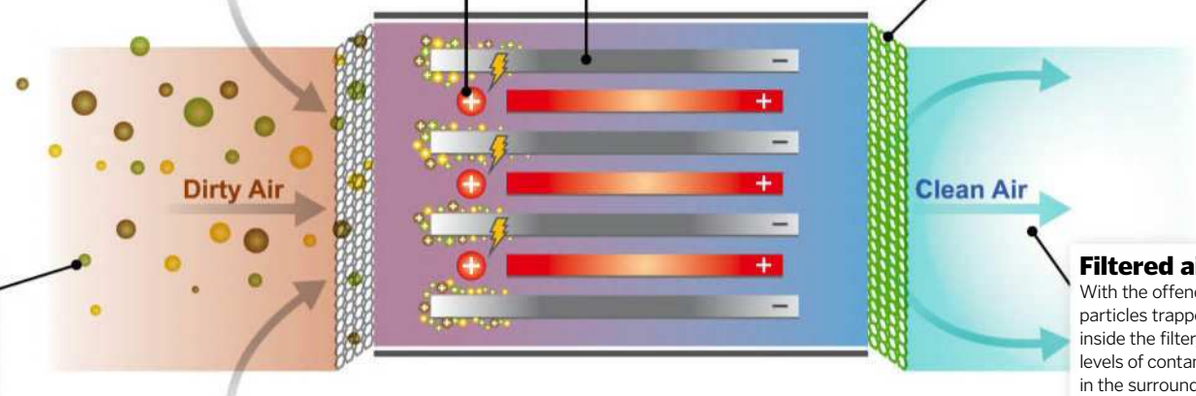
Air purifiers help to reduce the levels of contaminants, such as dust or dander, in your home. They are often beneficial for those with allergies or asthma, who may experience symptoms when exposed to high levels of such particles.

There are several types of purifier, and each kind works in a different way. HEPA (high efficiency particulate air) filters force air through materials that block the majority of particles larger than 0.3 microns in size. Other filters rely on highly adsorbent materials – such as activated charcoal – which are very porous and can trap other molecules within their structures.

Some of the most commonly used models are ionising purifiers, which give passing molecules – such as dust particles – either a positive or negative charge. The charged molecules are then attracted to metal plates within the filter (which carry opposing charges), removing them from the air.

Inside an ionising purifier

Find out how electrostatic induction can trap problematic particles



Ioniser
In this example, the positively charged ioniser causes passing atoms to lose an electron and therefore become positively charged themselves.

Attraction
The positively charged particles are attracted to the negatively charged metal plates within the filter.

Extra filters
Some ionising air purifiers include additional sections of filtering materials to clean up as many contaminants as possible.

Contaminants
Substances like tobacco smoke, mould spores, pollen or dust can irritate the lungs of people with allergies or asthma.

Filtered air
With the offending particles trapped inside the filter, the levels of contaminants in the surrounding air are reduced.

Would you eat your spoon?

Innovative company Bakeys think edible cutlery could be the answer to our plastic waste problem

As we battle to ban microbeads, do away with drinking straws and charge pennies for plastic bags, companies are getting creative. With the amount of plastic in our oceans set to triple by 2025, cutlery maker Bakeys want us to start eating our spoons.

Made from sorghum flour, rice flour and wheat flour, their unusual cutlery is a vegan, dairy-free alternative to plastic. They knead the ingredients with water before pressing the dough tightly into moulds, adding sugar, spices and other flavourings to boost the taste.

Sorghum grows with less water and nutrients than other grains, and it resists moisture, stopping the spoons dissolving. The low liquid content also allows the eco-cutlery to sit on shelves for months at a time without the need for preservatives. And, if you don't fancy eating it, your spoon will break down all on its own.

Bakeys are adopting the technique for chopsticks, forks, plates and other kitchen items, although knives are out. While a knife wouldn't dissolve completely as you ate, the sharp edge would dull rapidly as it got wet.


The ingredients in edible spoons are pressed tightly to resist moisture from your food

Inside the Apple HomePod

We take a look under the hood of Apple's smart speaker

Apple was a little late into the 'smart speaker' game when it released the HomePod months after Amazon and Google's speakers had appeared. However, that extra time allowed Apple to fine-tune its device to help create a well-rounded speaker that makes your music sound fantastic.

Thanks to a design that positions speakers all around the edges of the casing, your audio really will fill an entire room. The woofer at the bottom of the speaker is there to create deep bass notes. Normally, to get more powerful bass the woofer needs to be bigger, but Apple simply increased the size of the magnet that moves back and forth to create the sound, allowing the woofer to stay the same size but the sound to improve.

Of course, this is just the start. The HomePod has Siri built in, allowing you to talk to the speaker and have it carry out tasks for you. These can be simple requests, such as skipping a song or playing a particular playlist, or more complex tasks such as converting values, or even controlling other smart home devices like light bulbs and thermostats if they're set up with HomeKit, Apple's home control system. It's easy to set up too; iPhone users can just hold their phone near the speaker and tap a few buttons to have all their data sync across automatically. So how does all of this smart tech – and a great sound system – fit into such a small space?

How the HomePod works

What's inside Apple's Siri-enabled smart speaker system?

Acoustic mesh
This specially designed mesh is acoustically transparent, which means it protects the HomePod from dust and debris without affecting sound.

LED display
The top of the HomePod features an LED screen that lights up when you give voice commands – the colours are projected from below.

Microphones
Six microphones are attached in a ring around the core of the HomePod so that the speaker can hear you from any angle.

Touch sensor
You can activate the smart speaker with a touch if you wish – tiny sensors in this board recognise when you touch the screen.

Logic board
This is the 'brain' of the HomePod and contains the processor, Wi-Fi chip and more to help it communicate with you.

© Fixit; Google; Amazon; Sonos; Apple

Other smart speakers

Google Home
This smart speaker is a powerful competitor simply because it has Google behind it. It can answer most questions, and it looks great while doing it too – although not as good as the HomePod. Still, it's certainly more affordable.

Amazon Echo 2
The Echo features a taller, thinner design than the HomePod and comes with Amazon's Alexa assistant built in. Like Google Home, the sound quality here isn't as good as that of Apple's smart speaker, but it's also the cheapest of these four.

Sonos One
This speaker is more expensive than Google and Amazon's options but comes with Alexa built in and offers superior sound. Sonos will be adding support for Google Assistant before the end of the year too, giving users even more choice.

"Talk to the HomePod and have it carry out tasks for you"

Woofer
This large speaker pumps out powerful bass. The huge magnet allows it to remain compact while delivering deep sounds.

Tweeters
Seven smaller 'tweeter' speakers deliver the higher notes in your music to every angle from the circular speaker.

Power Supply 2
The chips and converters on the internal power supply take the AC and turn it into DC to power the smart speaker.

Power supply 1
The power supply is split in to two parts inside the HomePod, meaning you won't need a large external power brick.

Compact
The HomePod has specially designed parts so everything fits inside the small casing.

The HomePod is designed to look simple on the outside, but there's plenty of tech hidden within

3D printing made easy

We chat with Lauren Slowik from Shapeways about making 3D printing accessible to the world

Lauren is the manager of education and design evangelism for Shapeways, a world-leading 3D printing company that offers commercial-grade printing to the general public. Lauren teaches people how to design and print in different materials using 3D design software and additive manufacturing technologies. Now, Lauren is launching a free course that Shapeways are producing in partnership with the New York Public Library. The Make It, Print It, Sell It course will put the power of 3D creation and enterprise into the hands of anyone willing to learn.

Could you explain a little about Shapeways and your role in the company?
Shapeways is the world's largest online 3D printing service. We deliver 3D prints straight to your door, all printed on the most cutting-edge technology. We currently offer over 60 materials and finishes, and have factories and offices in New York and the Netherlands and partners around the globe. My role here at the company is to help lower the barrier to entry to 3D modelling and 3D printing. This means creating tutorials and accessible content that people can tap into for free.

How did you become involved in this industry?
I've been in consumer technology for 12 years, and then in 2011 I was in graduate school and started writing software for 3D scanning to fit clothing. I followed that train of thought and the next idea was "What do I do with all this 3D dimensional data? How can we get it back out of the computer and into reality?"

What do you enjoy the most about 3D printing?
I enjoy that it is a Wild West of sorts, that by being involved now at arguably the early stage is exciting because we're making the rules as we go along. It feels how I imagine the early days of personal computing must have been like in the 70s and 80s.

What sort of items are people making using Shapeways?
We're approaching our 10 millionth product printed, and we receive 140,000 new design uploads each month – so we're seeing everything! We're seeing our customers design everything from jewellery to model trains to home decor; so we're really enabling users to design, make and – interest permitting – sell.

What opportunities does this technology give to consumers?
We know people want to turn their ideas into products using 3D printing, but for the general consumer they don't have the technical skills to even know where to start. Shapeways wants to become the complete end-to-end platform helping people bring their creations to life, regardless of their technical experience or access to 3D printers.

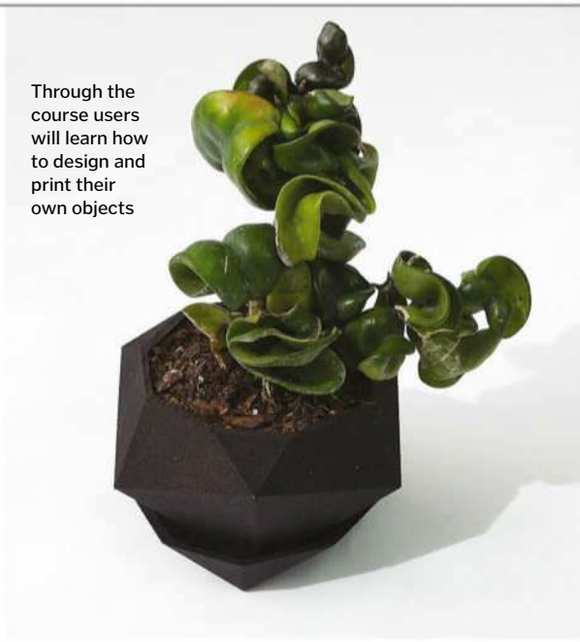
There is a new course you are launching soon - can you tell us what this will be about?
The course will be about learning the basics of 3D design for 3D printing using free and accessible software like Tinkercad and SketchUp. We developed the projects and content with the New York Public Library TechConnect program, which consists of free tech training for all library patrons. The course was also designed to give institutions like public libraries free resources so they could offer 3D printing to their community without needing to invest in 3D printers. The idea is after only 20–30 minutes anyone would be able to make something simple printable from scratch.

Do you have any favourite items you have 3D printed yourself? Or items other people are printing?
When I first began at Shapeways, we were hosting a six-month-long exhibition at the Museum of Arts and Design here in NYC and myself and my team 3D scanned nearly 7,000 museum visitors, and they went on to purchase tons of little 'mini-me's. That's gotta be one of my favourite projects. Nervous System makes the most incredible, uncanny interfaces to create generative jewellery, home goods and even full dresses all from a single print. Think about being able to customise your entire physical reality as much as a video game avatar or your social media – that's how big being able to 3D model and print is.

What do you think the future of 3D printing will look like?
In the future we hope it'll be so ubiquitous that you can have an idea, make a few gestures on your device, probably a VR/AR mixed reality design space, and voila! Have something completely custom produced just for you.

Shapeways has partnered with the New York Public Library's TechConnect Program to make 3D printing accessible to everyone with Make It, Print It, Sell It. Through a series of free online tutorials, you can learn how to make, print and sell your creations. The course will be available from 1 May 2018, and you can find out more at sites.google.com/a/nypl.org/techconnect/3d-pri

Shapeways offers users access to different 3D printing materials, including stainless steel and precious plated metals



Through the course users will learn how to design and print their own objects

"Shapeways wants to help people bring their creations to life, regardless of technical experience or access to 3D printers"

With 3D printing, you to create shapes that would otherwise be very difficult (or even impossible) to create with conventional manufacturing techniques

Users can design and print custom creations, like these Nintendo Switch handles

3D printing enables you to produce bespoke products, from practical tools to decorative items

The bagpipes

The sound of Scotland's national instrument is unmistakable, but how is it produced?

Throughout the Highlands of Scotland, the distinctive bellowing of tartan pipes can be heard cascading through the air. Bagpipes have been a part of Scottish tradition for centuries, however, their origins lie elsewhere. It's still unclear as to where exactly this type of instrument was first invented, but one theory is that the invading Roman army brought the pipes to Scotland from Egypt.

Bagpipes were originally used as an instrument for battle, and were first documented during the Battle of Pinkie in 1547. It is said the melody of pipes could be heard for up to 16 kilometres as the sound led Highlanders onto the battlefield.

In order to create their iconic and long-lasting sound, bagpipes rely on a continual flow of air to create a constant tune. There are many structural variations of bagpipes, but most comprise a bag, melody (chanter) pipe and drone pipes. The player blows into the aptly named blowpipe, filling the bag with air. It is the job of the player to continually fill the bag and squeeze the air out with their arm while playing the chanter. Air passes through reeds within the pipes, creating the continuous sound expelled from the drone pipes at the top of the bagpipes and the chanter at the base. Using holes in the chanter, the player can control the melody in the same way as any other reeded instrument.

These woodwind instruments are often called the 'third lung' due to their inflating motion

Playing the third lung

A continual air supply is key in controlling these Highland pipes

Drone pipes
These pipes produce a continuous melody as air passes through the reeds.

Reeds
Within each pipe are reeds. They vibrate as air is passed through, creating the characteristic sound of the bagpipe.

Blowing pipe
The player blows through this pipe continually to inflate the connected bag, which includes a valve to stop air escaping.

Pressure
The player will compress the air bag with their arm, controlling the amount of air that passes through each pipe.

Air bag
Air collects within the bag, circulating before being expelled through several connecting pipes.

Chanter
The higher-pitched pipe, the chanter, allows the player to control the melody.

Bagpipes require the player to fill the bag with enough air to pass through each of the four pipes

Bagpipe reeds were previously made from cane before plastic was introduced in modern-day versions

THE TRANS-SIBERIAN RAILWAY

In 1904, Russia achieved the impossible: after decades of work, they opened the world's longest railway

Words by **Laura Mears**

Built by hand through one of the harshest environments on Earth, the Trans-Siberian Railway stretches 9,258 kilometres from Moscow to Vladivostok. Hundreds of men died laying the tracks, and the project sent Russia to war with Japan, but it finally linked the West to the East.

Work on the line began when Russia was still under the rule of the Tsars. The capital of Alexander III's disjointed empire lay in the west, separated from the eastern border by desolate snow forests. The only way to cross was by wagon or along waterways that turned to ice during the winter. Russia's eastern ports froze over when the snow hit, and messages sent by telegram regularly went missing. Inside the country there was talk of revolution. Outside, Russia's eastern frontier was vulnerable to attack. They desperately needed a weatherproof transport network to unite the population.

Following in the footsteps of North America, Minister of Transport Count Sergei Witte suggested trains. A Trans-Siberian Railway could do for Siberia what the First Transcontinental Railroad did for the Wild West. However, the line would need to cover almost three times the distance. Russia didn't have America's resources – they lacked the money, the workforce and the experience. What's more, the tracks would have to pass through some of the world's roughest terrain. The railway would sit on permafrost, frozen for months at a time and liable to melt during summer. The tracks would cross rivers, travel around the world's largest freshwater lake and slice through mountains.

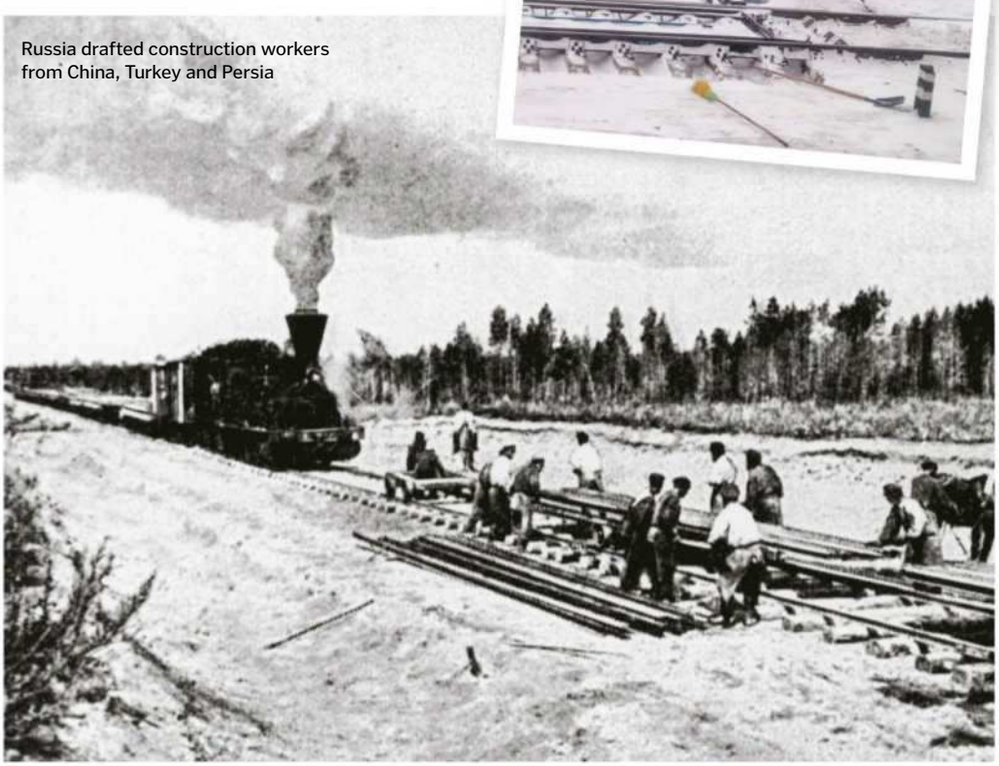
If they managed to pull it off, the rewards could be huge. The population in Siberia was thin and industry underdeveloped. But this inaccessible landscape, blanketed in snow for much of the year, contained most of Russia's resources. Siberia hides oil, coal, gas and diamonds. The Ural Mountains have magnetite, bauxite, gold, platinum, asbestos, talc, amethyst and topaz, and between the precious rocks there are fertile plains. Better transport links promised to make the country millions. Russia's poor would have access to new jobs. New markets would open with Japan, China and Korea, and exports could travel easily from Asia to Europe. Russia could become the gateway to the East.

Russia poured the equivalent of 50 million US dollars into the project, financing the new railway with loans and taxes. The treasury courted rich European investors, promising lavish trips to Asia. They made a deal with China, agreeing to extend the railway line into Manchuria, and they printed more money, risking the financial security of the empire.

The Tsar wanted the project finished within ten years, but the climate in Siberia made working during winter impossible. To save time, they planned to lay the track in six simultaneous sections. To cut costs, they would build a single iron rail instead of a double steel track, and bridges would be wood rather than metal or stone. There would be fewer sleepers to pin the track together, and they would build everything by hand – no machines or dynamite.

Gathering the men to build the track was challenging. Even with the promise of free accommodation, people were reluctant to move to Siberia from Russia's cities. Siberian natives disliked the idea of the railway and refused to work. In the end, men from China, Persia and Turkey made up much of the workforce, along with Russian prisoners and exiles. The convicts exchanged work for time off their sentences and spent their nights chained to wheelbarrows. For complicated tunnels and bridges, stonemasons

The Soviet Union upgraded the railway, replacing the iron tracks with two strong steel lines



Russia drafted construction workers from China, Turkey and Persia

The railway that started a war

The Trans-Siberian Railway extended Russia's reach into the East. A deal with China took the line into Manchuria, and in return Russia secured a lease for the ice-free Chinese naval base at Port Arthur. By 1900, with construction on the main line progressing, Russia started sending troops eastwards, but not everyone welcomed their arrival. Japan also had designs on Manchuria and the Korean Peninsula. In an effort to halt Russia's unwelcome expansion, they attacked Port Arthur in 1904.

With the Siberian portions of the railway still unfinished, Russia struggled to respond. Troops became stranded at Lake Baikal, unable to cross the frozen waters. After multiple defeats, Tsar Nicholas II eventually backed down. The Treaty of Portsmouth restored peace to the region, returning Manchuria to China and giving the South Manchuria Railway to Japan.

Japan attacked during the winter with the railway at its most vulnerable

were drafted in from Italy, a nation over 6,142 kilometres away.

More than 15,000 people worked on the project, toiling from dawn until dusk, which in the high latitudes of Siberia lasted deep into the night. The men used wooden shovels, rakes and pickaxes, hefting soil and stone with their hands and relying on horses to take the heaviest loads, which were eaten when they became too weak.

Poor planning stalled the project at every turn. Engineers contracted to survey the ground failed to map every stream, river and hill, and they didn't account for the meltwater that raced over the landscape in the spring. Flooding created swamps, anthrax spread through the animals and people fell to fevers transmitted by mosquitoes. Workers eventually resorted to wearing nets to keep the insects at bay.

Together they soldiered on, crossing rivers and bogs, sometimes working waist-deep in water. They cut paths through inaccessible forests and built lines in perilous valleys. Work only stopped in winter when the weather became too harsh.

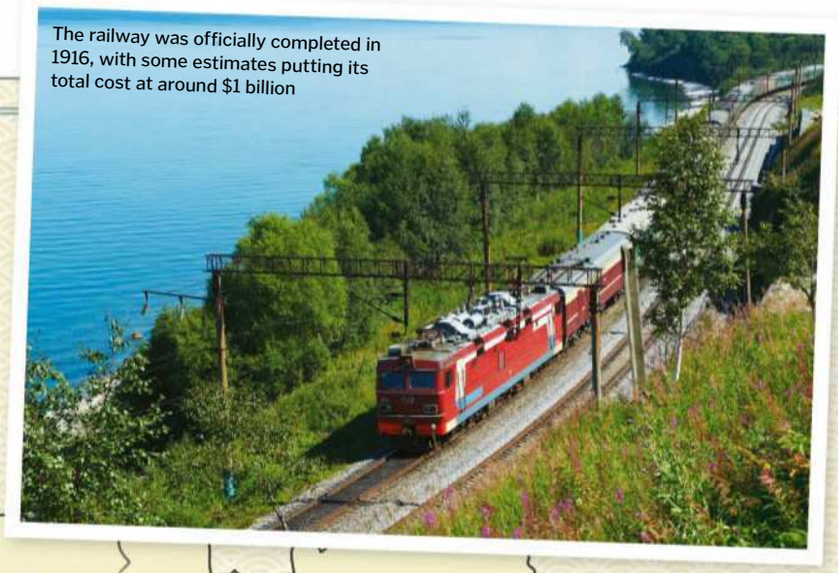
The most challenging section of track was at Lake Baikal. Bounded by mountains and coated with ice in the winter, it was all but inaccessible. The original plan was to use a boat to transport the carriages. Made in England, the Baikal Ferry had a reinforced steel hull and a propeller to cut through the ice. It was so enormous that they had to break it into chunks to get it to Siberia.

When it finally arrived, it wasn't up to the job. During the warmer months massive storms tossed the ferry off course and fog obscured the view. In the winter the ice was up to 2.7 metres thick and the propeller couldn't cut through.

Finding a way to cross the lake became urgent when Japan attacked Port Arthur in 1904, so they tried laying tracks over the ice – the first train fell straight through. They only solution was to go around, carving 38 tunnels through the granite cliffs on the shores.

As the project neared completion cost-cutting took its toll. The railway started to break before it was even finished. The complicated route and rapid construction meant that failures were common. The trains crawled slowly along the rickety lines and were often delayed, overcrowded and undersupplied. But, though broken, the railway was a triumph.

Built by hand across one of the most hostile environments in the world, it was an incredible feat of human endurance. It offered new opportunities for Russia's poor, opening a corridor to a new life. Around 5 million immigrants moved to Siberia between 1891 and 1914. In the 1950s, the Soviet Union upgraded the railway, adding a second track, steel rails, new tunnels and new bridges. Now it's one of the strongest railway lines in the world.



The railway was officially completed in 1916, with some estimates putting its total cost at around $1 billion

Riding the rails

The Trans-Siberian Railway is studded with historic towns and cities

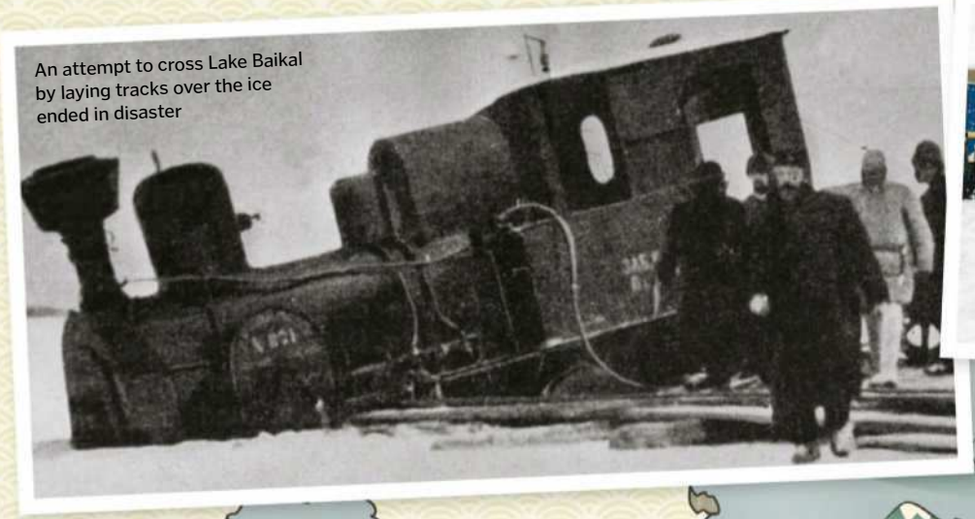
Yekaterinburg
Travellers to Yekaterinburg can visit the place where the Bolsheviks murdered Tsar Nicholas II and his family in 1918.

Moscow
Russia's capital is home to the Kremlin, Red Square and the world-famous Bolshoi Ballet.

Omsk
This concrete jungle lacks the architectural beauty of Russia's largest cities, but provides a welcome rest for rail travellers.

"Workers cut paths through inaccessible forests and built lines in perilous valleys"

Construction workers built the entire Trans-Siberian Railway by hand



An attempt to cross Lake Baikal by laying tracks over the ice ended in disaster

The Trans-Siberian Railway Network runs through one of the harshest environments on the planet

RUSSIA

CHINA

MONGOLIA

Krasnoyarsk
Home to the vast Stolby Nature Sanctuary, Krasnoyarsk is a popular stopover on the journey to Lake Baikal.

Baikal-Amur Mainline
Built on permafrost, this line provides an alternative route across northern Siberia.

Lake Baikal
This vast body of water is the oldest and deepest freshwater lake in the world.

Irkutsk
Eastern Siberia's main city, this is the place to stop if you want to visit Lake Baikal.

Trans-Mongolian
This line connects the Trans-Siberian Railway to Beijing via the Gobi Desert.

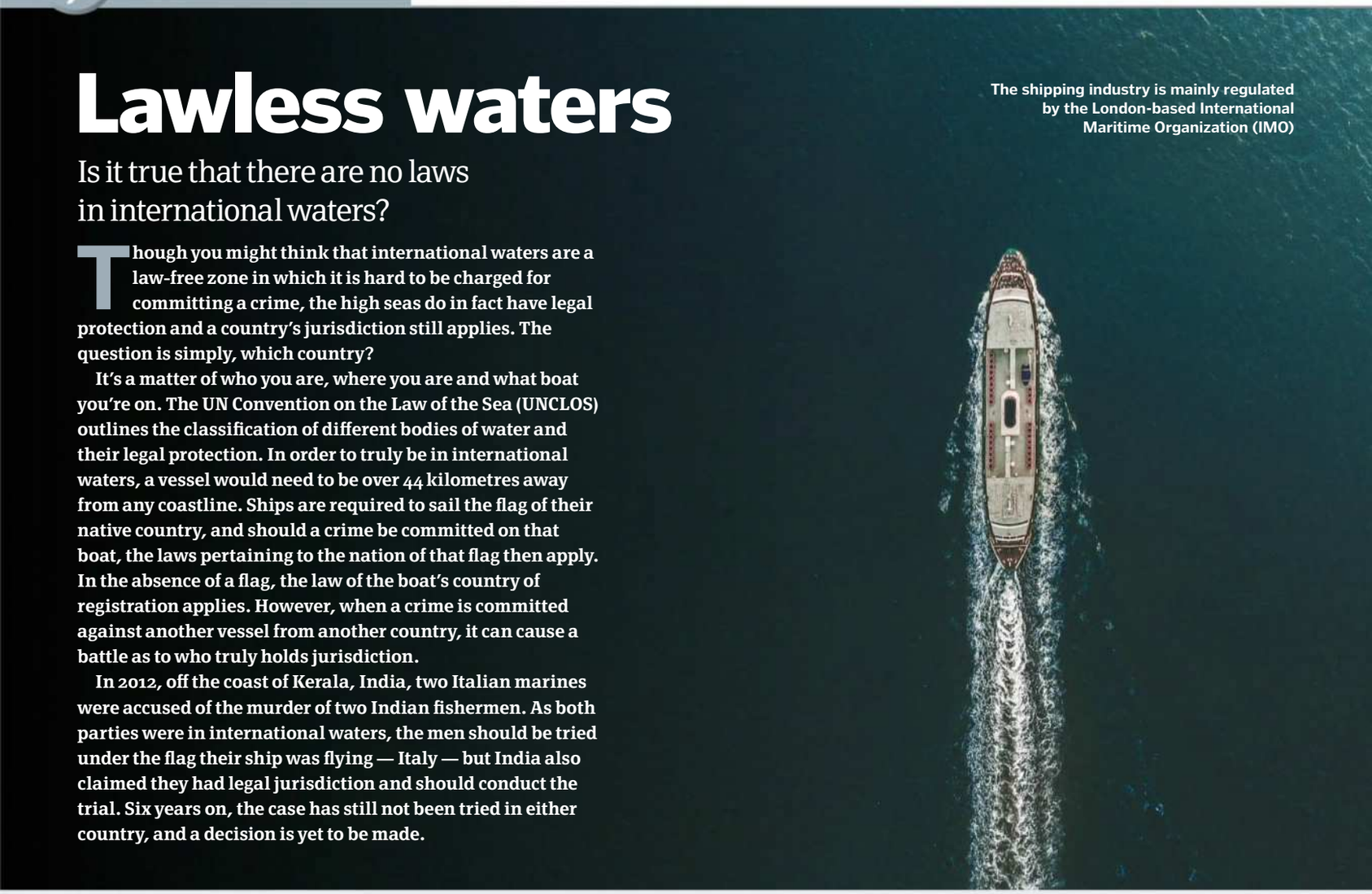
Trans-Manchurian
This historic stretch of railway passes through the Manchurian Plains of China.

Vladivostok
This Pacific port is the final stop on the line, promising sandy beaches and beautiful architecture.

KRASNOYARSK
TAYSHET
BRATSK
UST-KUT
SEVEROBAIKALSK
TYNDA
SKOVORODINO
KOMSOMOLSK-ON-AMUR
SOVETSKAYA GAVAN
KHABAROVSK
BELOGORSK
VLADIVOSTOK
HARBIN
CHANGCHUN
SHENYANG
BEIJING
DATONG
ERENHOT
ULAN BATOR
NAUSHKI
IRKUTSK
ULAN-UDE
CHITA
ZABAIKALSK
NOVOSIBIRSK

Lawless waters

Is it true that there are no laws in international waters?



The shipping industry is mainly regulated by the London-based International Maritime Organization (IMO)

Though you might think that international waters are a law-free zone in which it is hard to be charged for committing a crime, the high seas do in fact have legal protection and a country's jurisdiction still applies. The question is simply, which country?

It's a matter of who you are, where you are and what boat you're on. The UN Convention on the Law of the Sea (UNCLOS) outlines the classification of different bodies of water and their legal protection. In order to truly be in international waters, a vessel would need to be over 44 kilometres away from any coastline. Ships are required to sail the flag of their native country, and should a crime be committed on that boat, the laws pertaining to the nation of that flag then apply. In the absence of a flag, the law of the boat's country of registration applies. However, when a crime is committed against another vessel from another country, it can cause a battle as to who truly holds jurisdiction.

In 2012, off the coast of Kerala, India, two Italian marines were accused of the murder of two Indian fishermen. As both parties were in international waters, the men should be tried under the flag their ship was flying — Italy — but India also claimed they had legal jurisdiction and should conduct the trial. Six years on, the case has still not been tried in either country, and a decision is yet to be made.

The world's busiest station

Since its opening in 1885, Shinjuku Station has broken global records for commuter numbers

Subway services were added to Shinjuku Station in 1959

On average, 3.64 million people pass through Shinjuku Station every day, making it the world's busiest train station. Located in the southwest of central Tokyo, Shinjuku is served by five rail operators that bring people from all over the country and acts as the connection to the suburbs of Tokyo.

This transport labyrinth has 200 exits for services running from over 30 platforms and 20 tracks, and 12 train lines. The East Japan Railway Company alone serves 1.5 million people a day from the station. Despite its high volume of commuters, Japan's famous bullet trains do not pass through the station.

Busiest airport
Hartsfield-Jackson Atlanta International Airport, US

Busiest shipping lane
Dover Strait, UK

Busiest road
Ontario Highway 401, Canada

Laying a macadam road surface involved compacting the road covering with a steam road roller

The history of tarmacadam

How an accidental spillage and a sharp-eyed surveyor led to a modern road surface

In 1901, Edgar Purnell Hooley, a surveyor for Nottinghamshire County, was strolling around Denby in Derbyshire, England. As part of his role he was required to carry out odd jobs throughout the county. But on one particular day he came across an unusually smooth piece of road while passing a factory.

At the time, roads were just chipped pieces of small gravel, meaning that they quickly deteriorated as large ruts from wheels became embedded in them. The road became difficult to pass due to large amounts of dust, and sharp bits of stone able to puncture tyres. By 1820, a Scottish engineer by the name of John Loudon McAdam had created a basic road surface, but he had never found a way to stick the stones together.

The section of road Hooley was investigating looked remarkably pristine. He spoke with locals and learned that a barrel of tar had burst open across the road. In efforts to reduce the mess created by the sticky substance, a quick-thinking employee had dumped waste slag from a nearby iron works on top of the tar. This improvised resurfacing of the road had solidified and smoothed the track, inadvertently leading to the development of the modern tarmac road.

The following year, Hooley patented the process of heating tar and then mixing it with slag and broken stones. This new, hard-wearing road surface was successfully marketed as tarmacadam in honour of its original inventor. Once the recipe was perfected, Nottingham's Radcliffe Road became the first tarmac road in the world.

The first roads

The first roads were formed by humans following the game tracks created by wild animals. Over time, societies have made improvements by clearing obstacles like trees and stones from these primitive, narrow roads. As commerce increased and people moved around more to trade these trails were further improved by being flattened or widened, meaning they were able to be used to transport more human and animal traffic.

As civilisations developed and wheeled carts became more widespread, stone-paved streets were built in early cities such as those of Mesopotamia and ancient Egypt. But it was during the height of the Roman Empire that road transport really became efficient. The Romans created deep roadbeds with clay, gravel, chalk and stone allowing their armies to travel quickly between areas.

Macadam roads are still used today and feature small stones placed directly onto subsoil to make it mostly impermeable to water

The Airbus Beluga

Meet the whale of a plane designed to ferry oversized aircraft parts around the world

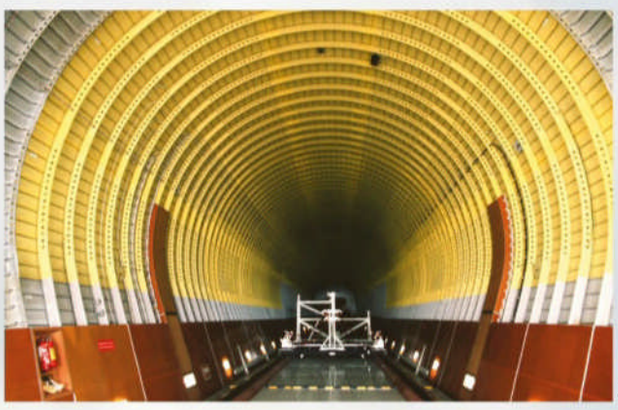
Each Airbus Beluga costs approximately $285 million (around £210 million) to build

As the aerospace industry boomed in the early 1990s, the infrastructure required to transport sections of an airplane became strained. The parts manufactured around Europe needed to come to one place for the final assembly. With the wings coming in from the UK, the tail and doors coming from Spain, the fuselage from Germany and the nose from France, this was no easy feat.

As parts got bigger and the demand for planes increased, the roads and railways quickly found themselves unable to keep up. It soon became apparent that engineers needed to find a better solution, and they looked to the sky for answers. It came in the form of a modified Airbus, one that was bigger and better than anything that had come before it.

Designed to carry parts of planes that hadn't even been invented yet, the Airbus A300-600ST was a perfect solution for the challenge. The modified Super Transporter made its first flight in September 1994 and was nicknamed 'The Beluga' in reference to the whale it resembles. The unusual horseshoe shape of the cavernous 7.3-metre-diameter fuselage resulted in the relocation of the pressurised cockpit to below the cargo-floor level.

The revolutionary design provided access to the cargo bay from the front without the need to disconnect the electrical, hydraulic and flight controls. This, and the utilisation of a roll-on-roll-off loading system, halved loading times compared to the Beluga's predecessor, the Super Guppy. Five Airbus Belugas are in service today, and another five – even larger – Beluga XL craft are currently in production. The first of these new-and-improved sky whales will be ready to take to the skies in 2019.



The huge cargo bay of an Airbus Beluga can carry about 47 tons

FREE NANO CURIOSITY BOX*

when you subscribe by 30 June 2018

The Curiosity Box is an award-winning Science, Tech, Engineering and Maths (STEM) subscription box for families. Each Nano Box contains everything you need for a hands-on home experiment!

Select the Nano Box of your choice from Sprouting Seeds, Sparky Structures or Rubber Band Racer!

*All pictures shown are for illustration only. Actual product may vary.

Every issue, delivered straight to your door

Never miss an issue

13 issues a year, and you'll be sure to get every single one

Delivered to your home

Free delivery of every issue, direct to your doorstep

Get the biggest savings

Get your favourite magazine for less by ordering direct

Pick the subscription that's right for you

MOST FLEXIBLE

Subscribe and save 20%

✔ Automatic renewal – never miss an issue

✔ Pay by Direct Debit

Recurring payment of £13 every three months, saving 20% on the retail price

DIRECT Debit Instruction to your Bank or Building Society to pay by Direct Debit

Originator's reference 7 6 8 1 9 5

Name of bank

Address of bank

Postcode

Account Name

Sort Code

Account no

Please pay Future Publishing Limited Direct Debits from the account detailed in this instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with Future Publishing Limited and, if so, details will be passed on electronically to my Bank/Building Society. Banks & Building Societies may not accept Direct Debit instructions for some types of account.

Signature

Date

GREAT VALUE

One-year subscription

✔ Great offers, available worldwide

✔ One payment, by card or cheque

A simple one-off payment ensures you never miss an issue for one full year. That's 13 issues, direct to your doorstep

☐ UK £53 (saving 18% on the retail price)

☐ Europe €78 ☐ USA $87 ☐ Rest of the world $97

Pay by card or cheque

Pay by Credit or Debit card

☐ VISA Visa ☐ Mastercard ☐ Amex

Card number

Expiry date

Pay by Cheque

I enclose a cheque for £

Made payable to *Future Publishing Ltd*

Signature

Date

Your information

Name

Address

Telephone number

Mobile number

Email address

Postcode

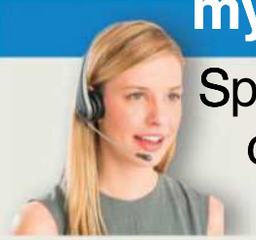
☐ Please tick if you want to receive any communications from Future and its group companies containing news, special offers and product information.

Please post this form to

Future Publishing Ltd, 3 Queensbridge, The Lakes, Northampton, NN4 7BF, United Kingdom

Order securely online

myfavouritemagazines.co.uk/curiosity



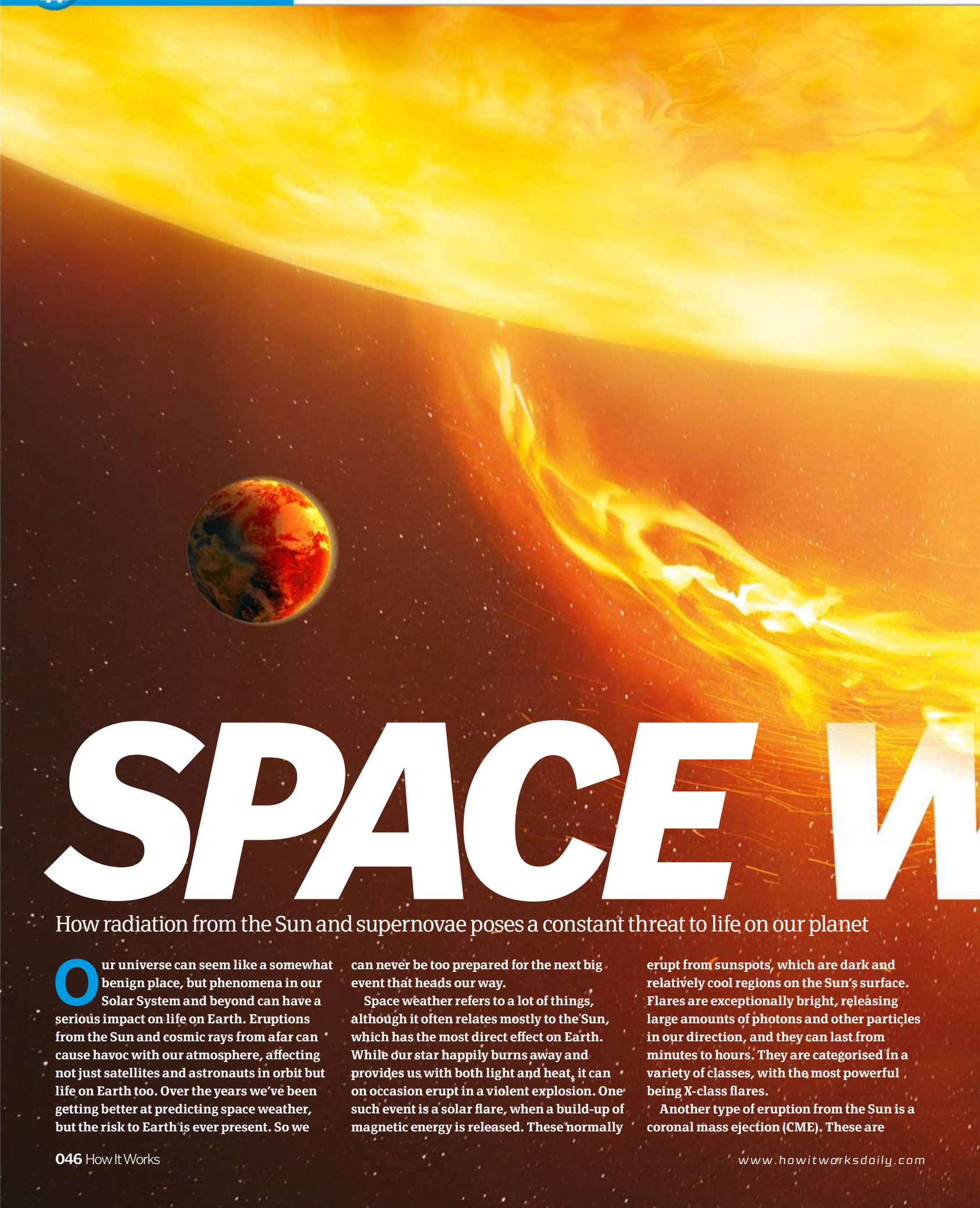
Speak to one of our friendly customer service team

Call **0344 848 2852**

These offers will expire on Saturday 30 June 2018

Please quote code **CURIOSITY**

Please use the full web address to claim your free gift. Gift available to new print subscriptions. Gift is only available for new UK subscribers. Gift is subject to availability. Please allow up to 60 days for the delivery of your gift. In the event of stocks being exhausted we reserve the right to replace with items of similar value. Prices and savings quoted are compared to buying full-priced print issues. You will receive 13 issues in a year. Your subscription is for the minimum term specified and will expire at the end of the current term. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) or are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **www.bit.ly/magterms**. Offer ends 30 June 2018.



SPACE W

How radiation from the Sun and supernovae poses a constant threat to life on our planet

Our universe can seem like a somewhat benign place, but phenomena in our Solar System and beyond can have a serious impact on life on Earth. Eruptions from the Sun and cosmic rays from afar can cause havoc with our atmosphere, affecting not just satellites and astronauts in orbit but life on Earth too. Over the years we've been getting better at predicting space weather, but the risk to Earth is ever present. So we can never be too prepared for the next big event that heads our way.

Space weather refers to a lot of things, although it often relates mostly to the Sun, which has the most direct effect on Earth. While our star happily burns away and provides us with both light and heat, it can on occasion erupt in a violent explosion. One such event is a solar flare, when a build-up of magnetic energy is released. These normally erupt from sunspots, which are dark and relatively cool regions on the Sun's surface. Flares are exceptionally bright, releasing large amounts of photons and other particles in our direction, and they can last from minutes to hours. They are categorised in a variety of classes, with the most powerful being X-class flares.

Another type of eruption from the Sun is a coronal mass ejection (CME). These are

/EATHER

Words by **Jonny O'Callaghan**

sometimes associated with solar flares, although the exact relationship is unknown. CMEs, like solar flares, are also the result of magnetic fields building up, but they instead hurl large amounts of matter into space. They can look like large fans of gas zooming out, with the hot plasma they produce taking up to three days to reach us. Using telescopes we can see and monitor both solar flares and CMEs before they reach Earth.

The Sun can produce other space weather too. High-speed solar wind, appearing over holes in the outer atmosphere (corona) of the Sun, can head towards Earth at speeds of up to 800 kilometres per second. Solar energetic particles (SEPs), meanwhile, are high-energy particles that can be caused by both solar flares and CMEs. Carrying a large amount of energy, they can cause considerable damage if they directly hit a spacecraft.

From outside our Solar System, galactic cosmic rays (GCRs) can also be sent in our direction. These highly energetic particles constantly bombard our planet and are thought to be produced by explosive events like supernovae. When the Sun is at its most active, known as its solar maximum, it does a good job of deflecting GCRs from our planet. However, during a solar minimum every 11 years, Earth is more at risk from GCRs,

The L5 mission

How ESA's bold proposal would help predict incoming solar weather

The Sun
As the Sun rotates, a coronal mass ejection (CME) or solar flare can come into view.

L1
A spacecraft at L1 sees solar weather at the same time as Earth, so it doesn't give us the same advance warning as L5.

Incoming particles
Utilising L5 could give us more accurate information on the speed of particles heading for Earth.

Magnetic field

L5
L5 is located about 60° behind Earth in its orbital plane around the Sun. With a side-on view, a probe positioned here can judge the speed of any solar ejections heading to Earth.

Advanced warning
A spacecraft at the L5 position would see the Sun's surface up to five days before it rotates into view of Earth.

Solar eruptions can produce stunning auroras near the poles

Ready for the storm

Early in 2018, the European Space Agency (ESA) announced it would be looking into a novel proposal to monitor space weather. While most space weather satellites are positioned in line with the Sun and Earth, this mission would be placed in a position of gravitational stability lagging behind Earth's orbit, known as Lagrange Point 5 (L5).

No mission has gone to this region before, but it offers a number of benefits. Being positioned to the 'side' of the Sun (relative to Earth), it could give us an early warning of the speed and direction of an ejection heading our way. This is because it could see the eruptions on the side of the Sun before it rotates into our view, so we'd know what was about to head our way. The ESA hopes to select a final design for the mission in mid-2019.

ESA's L5 mission will be positioned behind Earth in its orbit around the Sun

which, like SEPs, can damage spacecraft. Fortunately, thanks to our atmosphere they pose little threat to us on Earth, but astronauts travelling into space in the future may have to contend with them a bit more.

All of these space weather events can have an impact on Earth, from minor to major. The most noticeable are the auroras produced at the north and south poles as particles from a CME release other particles trapped in our planet's magnetosphere, which in turn funnel down to the poles and trigger reactions in oxygen and nitrogen molecules. The result can be a stunning light show of flashing green and purple. However, these geomagnetic storms can also affect communications with spacecraft and expose people flying in planes to more radiation. Flights are even sometimes rerouted to avoid their worst effects.

During periods of intense space weather the number of high-energy particles around Earth increases, particularly in two bands of trapped radiation that surround our planet known as the Van Allen belts. If a high-energy particle strikes a satellite in just the right way it can cause anomalies such as switching a circuit, or more seriously it can damage or knock out the satellite entirely. Sometimes satellites are put into safe mode during the strongest space weather events to protect them from the incoming radiation.

Knowing when these events will occur is therefore very important in order to allow us the time to prepare satellites to ride out the storm. Some severe events can also affect communications and power grids on Earth, which must be similarly maintained to avoid damage.

To track space weather events we have a number of spacecraft that continually monitor the Sun, each one looking for any eruptions that might send particles our way. This can give us several days' warning for the most powerful events, with the National Oceanic and Atmospheric Administration (NOAA) giving storms a rating from 1 (minor) to 5 (severe) to let people know how dangerous an incoming storm is.

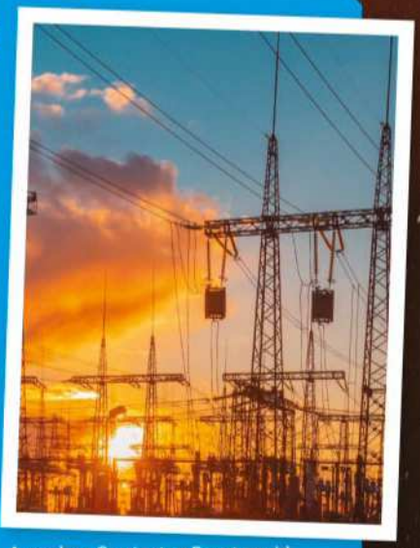
Over the years we've certainly got better at monitoring space weather, but there is always the risk of an exceptionally large solar eruption in the future causing huge issues. We can mitigate most problems, but it's always better to be prepared if and when the next big one does hit.

Major space weather events

In 1859, a solar storm known as the Carrington Event struck Earth, causing one of the largest geomagnetic storms on record. At the time it only resulted in a few telegraph pylons emitting sparks, but were the same event to happen again today the results to our infrastructure could be catastrophic.

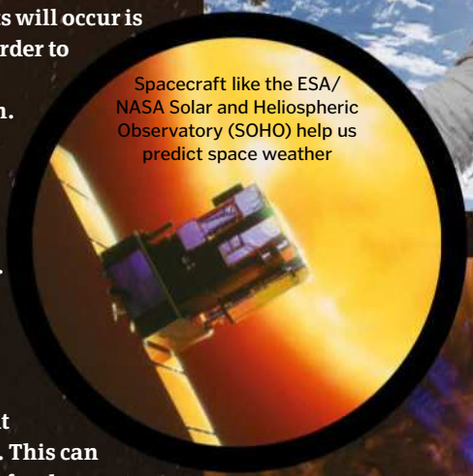
The Carrington Event was so powerful that, by some accounts, the auroras it produced were bright enough to read a newspaper by. But it's the impact on the ground that is of most concern. The high-energy particles from such an event would ionise our upper atmosphere, sending radio communications haywire. Any associated radiation could pose a danger to astronauts in orbit, while slower-moving charged particles could cause huge disruptions, enough to bring down the electrical grid.

Fortunately, we're getting better at predicting storms like this, so hopefully if one happens again we'll be ready.

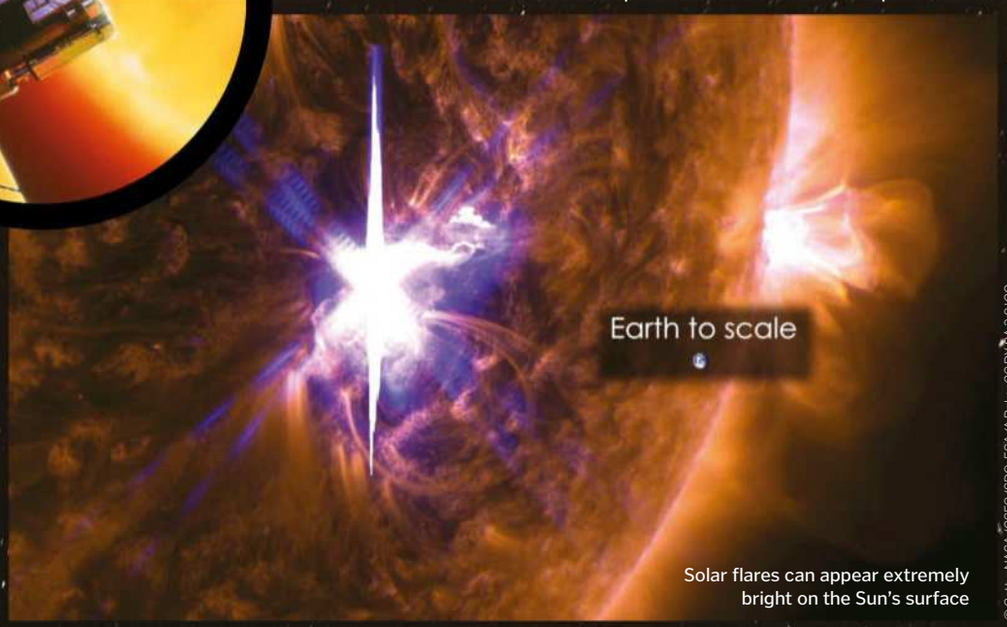


A modern Carrington Event could knock out our electric grid

Astronauts on a spacewalk can be at risk from space weather



Spacecraft like the ESA/NASA Solar and Heliospheric Observatory (SOHO) help us predict space weather



Solar flares can appear extremely bright on the Sun's surface

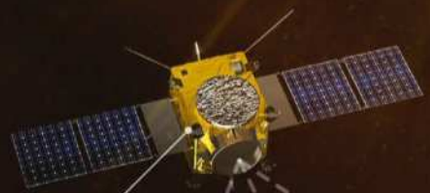
Impact of space weather

How space weather affects life both on Earth and in orbit

Cosmic rays
Radiation from distant phenomena like supernovae can pose a threat to our planet.

Astronaut radiation
Astronauts are exposed to more radiation than Earthlings as they are outside our planet's protective atmosphere.

Solar protons
A 'proton storm' can occur when solar particles are accelerated by the Sun's activity, reaching Earth in less than an hour.



Radiation damage
Satellites can be damaged by incoming radiation, so precautions must sometimes be taken.

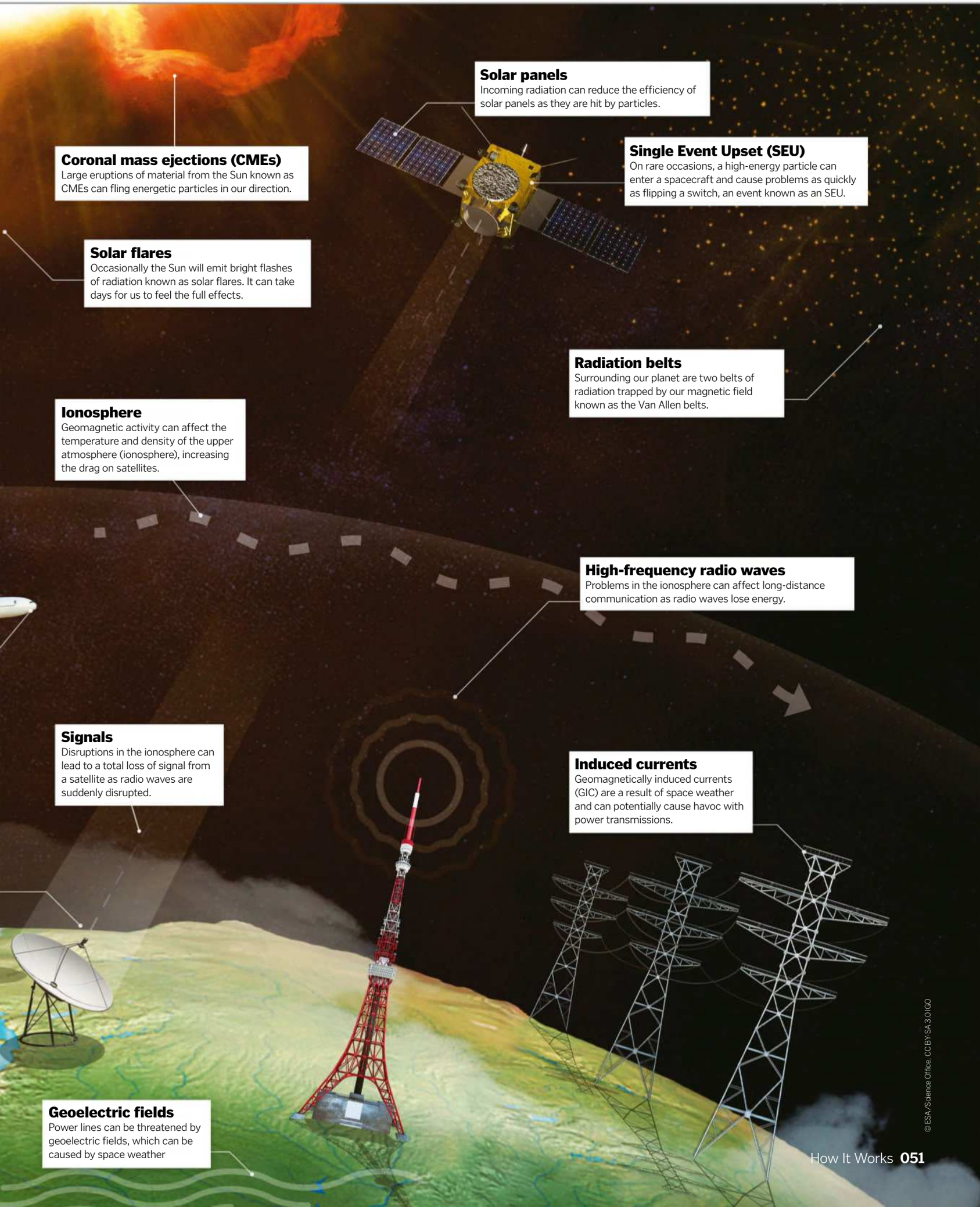
Navigation errors
Severe geomagnetic storms caused by the Sun can result in errors in GPS accuracy when navigating.

In flight
Flying on a plane increases your exposure to cosmic radiation, although not by too much.

Auroras
While space weather can be dangerous, it is also the cause of wonderful auroras on our planet.

Reception
Receiving a signal from space, such as position information, can be more difficult during a space weather event.

Drilling
Geomagnetic activity caused by space weather can cause issues when directing a borehole to drill for oil or gas.



Robert Lawrence died aged 32, leaving behind a wife and young son

Lawrence's appointment as the first African-American astronaut attracted a lot of press attention at the time

"His curiosity for science had led him to dream of exploring space and learning more about the universe"

A life's work

A life tragically cut short

1935
Born on 2 October in Chicago, Illinois, Lawrence shows an early interest in chemistry and flying.

1952
Lawrence graduates in the top ten per cent of his class at Englewood High School, aged just 16.

1956
He earns his bachelor's degree in chemistry from Bradley University at 20 years old.

1965
Aged 30, Lawrence obtains a PhD in physical chemistry from The Ohio State University.

Robert Lawrence

Robert Lawrence (second from left) with his fellow MOL Group 3 astronauts

The world's first African-American astronaut who never made it into space

Major Robert Lawrence Jr was a true pioneer of aerospace research, but he remained largely unknown for decades after his life was tragically cut short.

Growing up in a poor neighbourhood in Chicago, Lawrence showed an early interest in science, requesting a bigger and more advanced chemistry set for Christmas each year. This, teamed with a deep passion for model airplanes, meant young Robert was destined for a career as an astronaut.

After graduating from the US Air Force (USAF) Test Pilot School with 2,500 flying hours under his belt, Lawrence was a natural fit for the Manned Orbiting Laboratory (MOL) programme, a joint project between the USAF and the National Reconnaissance Office. He became the first African-American astronaut selected by any space programme when he was recruited as a member of the third group of aerospace research pilots for the MOL programme.

At the time the civil rights movement was still ongoing in the US and racial segregation was rife, but Lawrence remained remarkably modest about his achievement: "This is nothing dramatic," he said. "It's just a normal progression. I've been very fortunate."

Not only had Lawrence become the first African-American astronaut, he was also the only selected MOL astronaut with a doctorate, having obtained a PhD in physical chemistry from The Ohio State University. His curiosity for science had led him to dream of exploring space and learning more about the universe, but sadly he never made it into orbit.

Just six months into his training for the MOL programme, Lawrence was killed in a plane crash at Edwards Air Force Base in California. He had been serving as an instructor for another pilot practising landing techniques that would later be used in the Space Shuttle programme, but the F-104 Starfighter they were flying hit the runway too soon. Both pilots ejected from the crash, but although the trainee escaped with major injuries, Lawrence died instantly.

Two years later the MOL programme was cancelled, and several of its members were transferred to NASA to fly on Space Shuttle missions. If he had lived, Lawrence would surely have joined them.

Despite being recruited for a space mission, Lawrence was initially not formally recognised as an astronaut, as he never met the criteria of flying 80.5 kilometres above the Earth. Because of this his name was left off the Astronauts' Memorial Foundation's Space Mirror at the Kennedy Space Center, a national memorial dedicated to those who had lost their lives in US space programmes, and his legacy was in danger of being forgotten.

However, in 1997, after decades of bureaucratic struggle, his name was finally inscribed and his incredible achievement as a space pioneer was rightfully honoured.

THE BIG IDEA

The Manned Orbiting Laboratory programme

Announced to the public in 1963, the MOL programme was pitched as a series of space missions to figure out the 'military usefulness' of putting humans into space. However, the actual purpose of the mission was classified, as it was really intended for spying on the Soviet Union. The plan was to launch a series of mini space stations, each occupied by two-man crews, into low-Earth orbit to obtain high-resolution photographs of America's Cold War adversaries. The programme was cancelled in 1969 before any launch took place as developments in unmanned surveillance systems became more cost-effective.

The Manned Orbiting Laboratories would have launched aboard modified NASA Gemini capsules

IN LAWRENCE'S FOOTSTEPS

1 Guion (Guy) Bluford

It took another 16 years after the death of Robert Lawrence for an African-American to finally make it into space. Philadelphia-born Guy Bluford was accepted into NASA's astronaut training programme in 1978 and flew aboard the Space Shuttle Challenger for the first time in 1983. He completed three more NASA missions – compiling 688 hours in space – by the time of his retirement in 1993.

2 Dr Mae Jemison

After working as a general practitioner and Peace Corps medical officer, Dr Jemison of Alabama made a career change and applied for NASA's astronaut training programme. In 1987 she became the first African-American woman to be accepted into the programme and in 1992 flew into space aboard the Endeavour mission, becoming the first African-American woman to go into space.

June 1967
In June, Lawrence completes US Air Force Test Pilot School at Edwards Air Force Base in California.

June 1967
Immediately after completing pilot training, Lawrence is selected for the Air Force's MOL programme.

December 1967
On 8 December, Lawrence is tragically killed in an airplane crash aged just 32.

September 1997
In September, the crew of the Space Shuttle Atlantis carries Lawrence's MOL mission patch into orbit in tribute to him.

December 1997
On the 30th anniversary of his death, Lawrence's name is engraved on the Space Mirror Memorial at the Kennedy Space Center.

2017
On the 50th anniversary of his death, NASA leaders honour Lawrence in a ceremony attended by hundreds.

Ultraluminous X-ray sources

What causes these bright beacons to shine across the cosmos?

In our universe we keep finding strangely bright objects that fall somewhere in brightness between a star and the centre of an active galaxy. They're called ultraluminous X-ray sources (ULXs), but at the moment we're not quite sure what's causing them.

There's about one ULX per galaxy on average, each shining extremely bright with X-rays. Some of them may be intermediate-mass black holes, or even smaller black holes, blasting out energy as they suck in matter. Others are thought to be the result of neutron stars – the remnant cores of massive stars that have exploded.

Neutron stars are extraordinarily compact, containing more than the mass of our Sun squashed into a city-sized sphere. As they draw in material they heat up and emit more X-ray radiation until they reach a point called the Eddington limit, where the outgoing X-rays start pushing matter away, possibly giving rise to a ULX.

So far we've found about four ULXs that look like they're caused by neutron stars and a number of others that we think might be black holes, but the jury is still out on exactly how they work.

A ULX is seen here in M51, also called the Whirlpool Galaxy

Jupiter's cyclones

Recent data is giving us a whole new look at our Solar System's biggest planet

NASA's Juno spacecraft entered orbit around Jupiter in July 2016, and since then we have been treated to a feast of data and images. One of the most recent discoveries, announced in March 2018, was that Jupiter's storms were unlike anything we see on Earth.

Infrared images taken by the Juno spacecraft, like the example below, have shown that each pole of Jupiter has a fascinating polygonal pattern of cyclones, with winds reaching speeds of up to 350 kilometres per hour. At the north pole a central cyclone is surrounded by eight more that measure up to 4,600 kilometres across. At the south pole there are just five surrounding cyclones, but they measure up to 7,000 kilometres across. The cyclones at both poles are so densely packed together that they are almost touching each other, but they're still able to maintain their individual shapes.

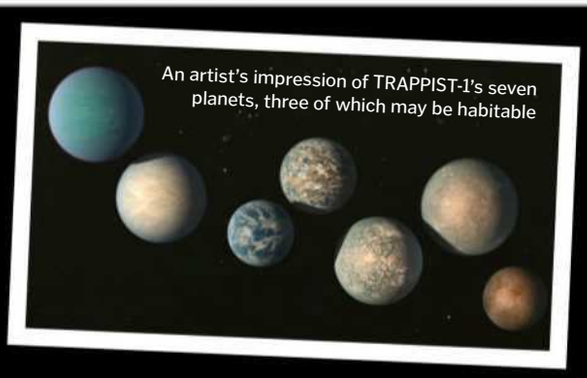
Juno is the first mission that's been designed to fly over Jupiter's poles, so it's the first chance we're really getting to have a good look at them. And how weird they're turning out to be.

Jupiter's south pole, as seen by Juno's Jovian Infrared Auroral Mapper (JIRAM)

Thanks to Juno, we have gained new insights into Jupiter's storms

An update on the TRAPPIST-1 system

What have we recently discovered about this intriguing exoplanet system?


An artist's impression of TRAPPIST-1's seven planets, three of which may be habitable

Since the record-breaking discovery of its seven Earth-sized planets was announced in February 2017, the TRAPPIST-1 system has stirred excitement and curiosity among the scientific community. Located almost 40 lightyears away from us, the exoplanet system's rocky planets orbit a cool, red dwarf sun. To make things even more interesting, three of the planets (TRAPPIST-1e, f and g) are located within the star's habitable zone, a region where temperatures are suitable for liquid water to exist. The system's age has recently been narrowed down to between 9.8–5.4 billion years, meaning that it may be twice as old as our own Solar System.

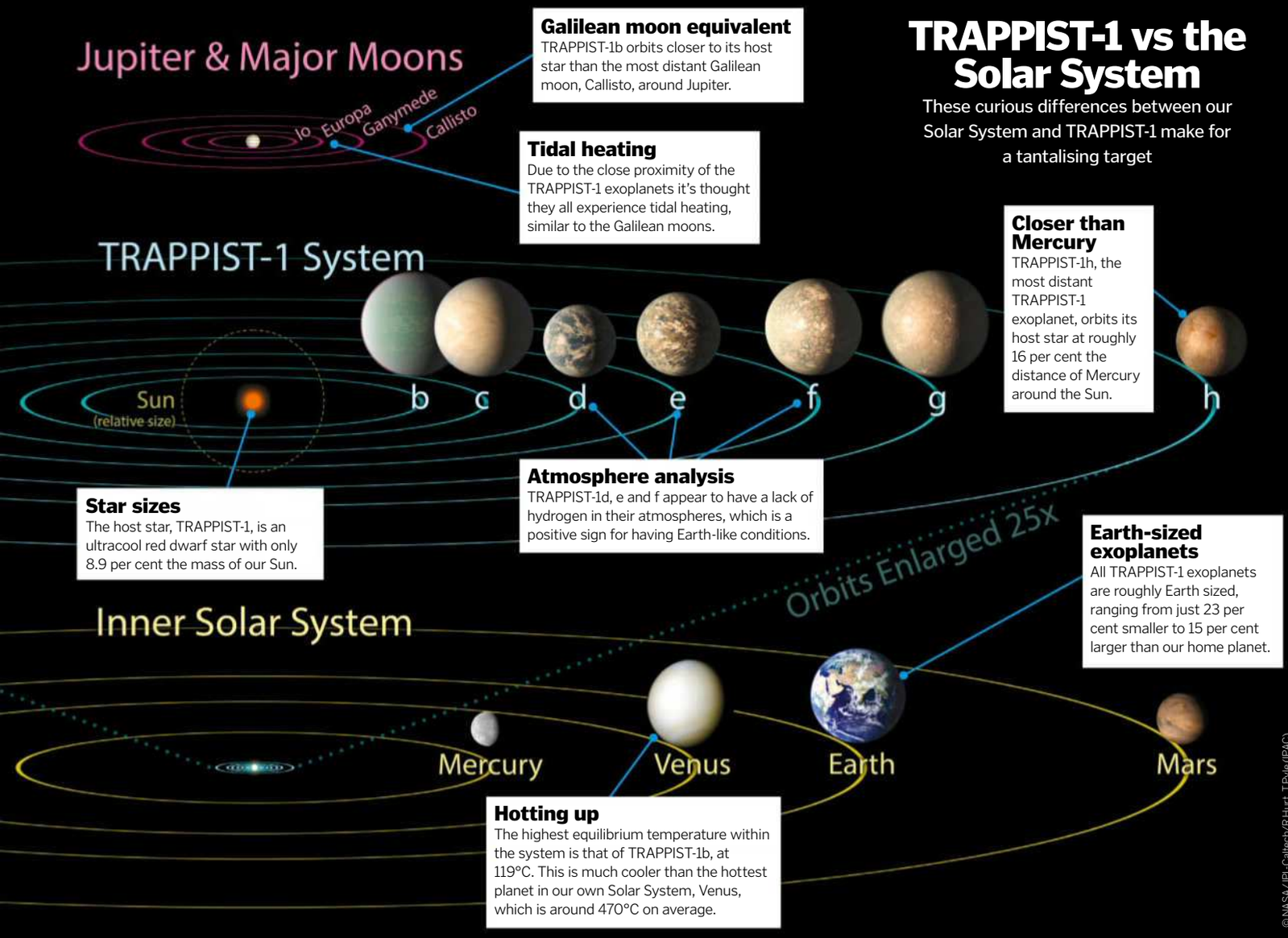
In May 2016, researchers using The Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile announced the discovery of three planets in the system. After follow-up observations using the Spitzer Space Telescope and other ground-based observatories, a total of seven roughly Earth-sized worlds were revealed.

This spark of scientific curiosity has continued to reveal new gems of information, and other observatories continue to collect further data. When Hubble recently examined the atmospheres of TRAPPIST-1d, e and f, the only thing it could decipher was a lack of hydrogen. This is a positive sign, as it means that there could be higher concentrations of heavier elements like those in Earth's atmosphere, making for a more exciting prospect of habitability.

Red dwarfs are the most common star types in the galaxy, so this potentially habitable system around TRAPPIST-1 is a promising discovery in our hunt for alien life.

TRAPPIST-1 vs the Solar System

These curious differences between our Solar System and TRAPPIST-1 make for a tantalising target



Galilean moon equivalent
TRAPPIST-1b orbits closer to its host star than the most distant Galilean moon, Callisto, around Jupiter.

Tidal heating
Due to the close proximity of the TRAPPIST-1 exoplanets it's thought they all experience tidal heating, similar to the Galilean moons.

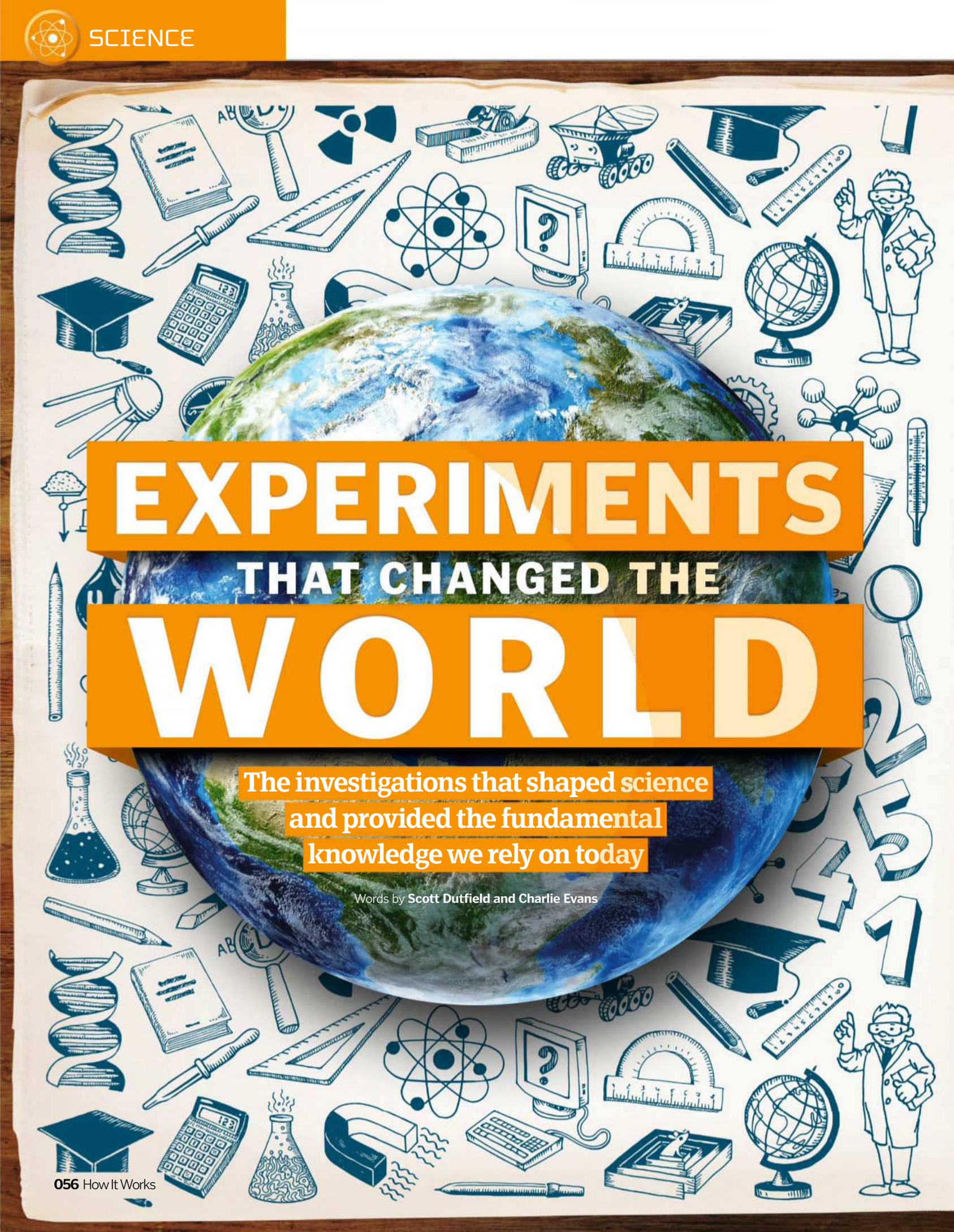
Closer than Mercury
TRAPPIST-1h, the most distant TRAPPIST-1 exoplanet, orbits its host star at roughly 16 per cent the distance of Mercury around the Sun.

Star sizes
The host star, TRAPPIST-1, is an ultracool red dwarf star with only 8.9 per cent the mass of our Sun.

Atmosphere analysis
TRAPPIST-1d, e and f appear to have a lack of hydrogen in their atmospheres, which is a positive sign for having Earth-like conditions.

Earth-sized exoplanets
All TRAPPIST-1 exoplanets are roughly Earth sized, ranging from just 23 per cent smaller to 15 per cent larger than our home planet.

Hotting up
The highest equilibrium temperature within the system is that of TRAPPIST-1b, at 119°C. This is much cooler than the hottest planet in our own Solar System, Venus, which is around 470°C on average.



EXPERIMENTS THAT CHANGED THE WORLD

The investigations that shaped science and provided the fundamental knowledge we rely on today

Words by **Scott Dutfield and Charlie Evans**

DID YOU KNOW? *Galileo was an astronomer, physicist, mathematician, philosopher, and discovered four of Jupiter's moons*

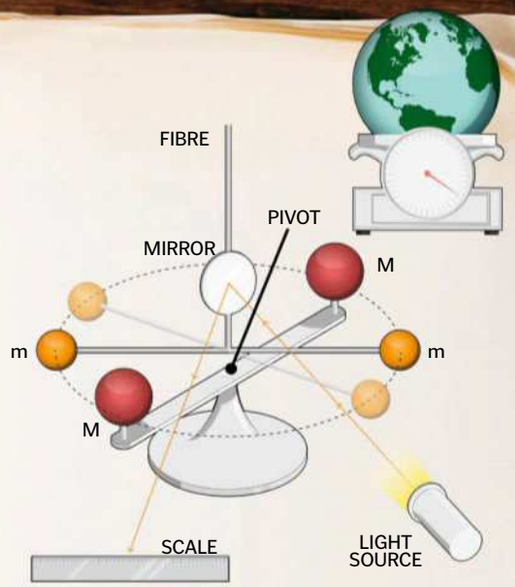
Cavendish weighs the world

England, 18th century

Not only did the solitary and eccentric Henry Cavendish discover hydrogen, but he also successfully measured the weight of the world. His ambitious experiment used a special piece of equipment called a torsion balance, and in 1798 he reported his results. By measuring the gravitational attraction between two different sized lead spheres, he calculated the Earth's density.

The apparatus consisted of an 1.8-metre wooden rod that had a 0.73-kilogram lead sphere attached to each end, suspended from a wire. A separate system of two larger 159-kilogram lead balls were placed close to the smaller balls. This exerted enough gravitational force so that when the weights were tugged slightly the rod twists (a telescope was used to observe this). Cavendish performed his experiments in a dark and wind-proof to prevent any external air currents and temperature differences affecting his results. He was able to calculate the Earth's density by using the ratios of the forces between the spheres and the gravitational attraction of the Earth to the spheres.

Incredibly, his results were very accurate, and his great experiment meant we could also calculate the mass of the Sun and the Moon and even other planets in our Solar System.



Cavendish's experiment to measure the weight of the world yielded results almost as accurate at today's calculations

Galileo Galilei and the Leaning Tower of Pisa Experiment

Italy, 16th century

Imagine you drop a bowling ball from one hand and a feather from the other. Which will fall faster? It is obviously the bowling ball, but this doesn't reflect the nature of the force of gravity.

Greek philosopher Aristotle had proposed that objects fell at different rates because gravity would act more strongly on heavier objects, but it turns out that the feather falls slower only because of air resistance. If you could perform the same experiment in a vacuum, the feather and ball will hit the ground at exactly the same time.

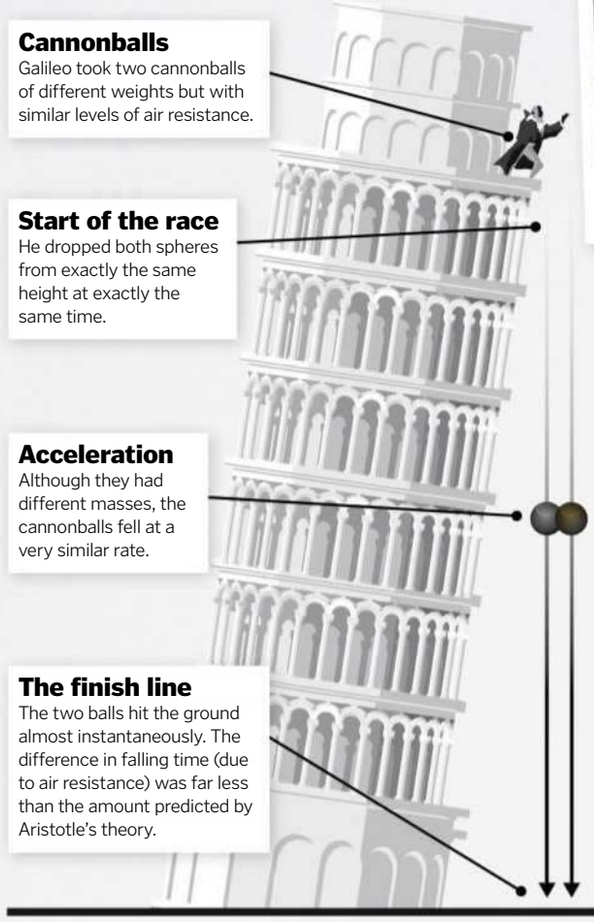
It is difficult to separate fact from legend, but the story goes that Aristotle's theory of gravity went unchallenged until Italian polymath Galileo Galilei disproved it. Though he spent the last years of his life imprisoned for going against the popular beliefs of the time, his work on speed, velocity, gravity and free fall provided the foundations of the understanding of how the planets and Solar System moved.

Hundreds of years after his death his experiment was repeated on the Moon – unsurprisingly, Galileo was right.

Apollo 15 commander David Scott replicated Galileo's experiment on the Moon in 1971

Galileo's cannonball experiment

Legend has it that Galileo climbed the Leaning Tower of Pisa to test his hypothesis



Cannonballs
Galileo took two cannonballs of different weights but with similar levels of air resistance.

Start of the race
He dropped both spheres from exactly the same height at exactly the same time.

Acceleration
Although they had different masses, the cannonballs fell at a very similar rate.

The finish line
The two balls hit the ground almost instantaneously. The difference in falling time (due to air resistance) was far less than the amount predicted by Aristotle's theory.

Under the near-vacuum on the Moon, the hammer and feather fell at the exact same rate

Mendel's peas

Czech Republic, 19th century

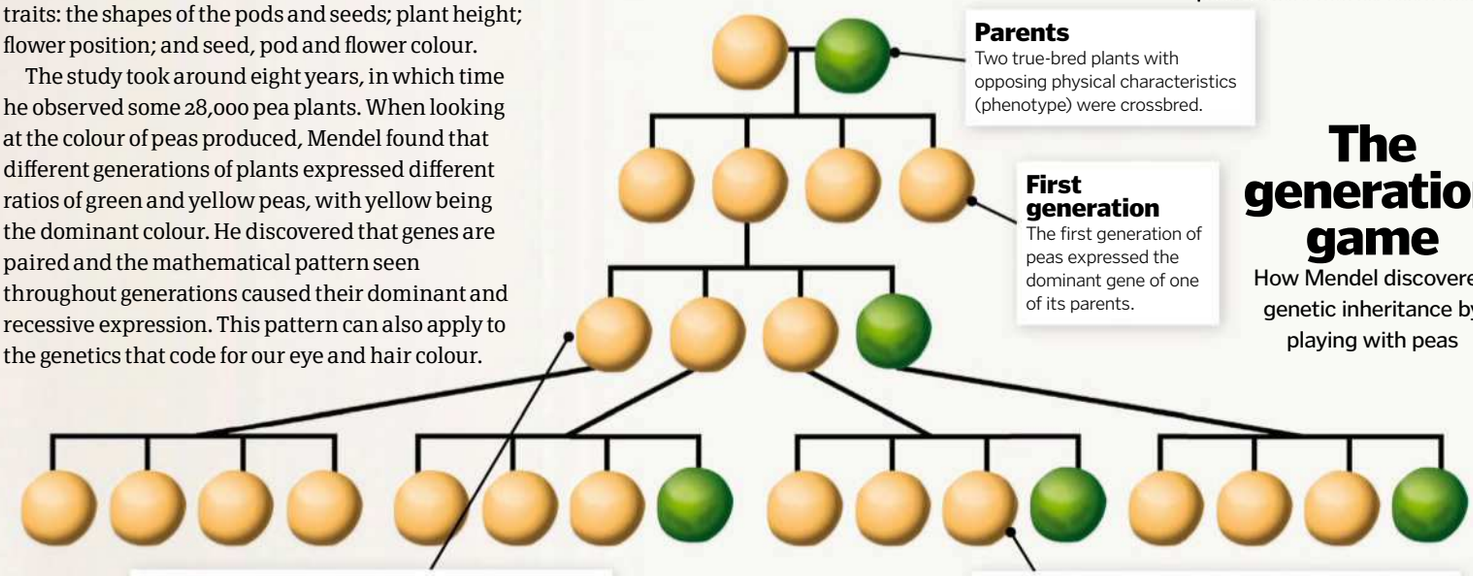
How do we inherit our genes from our parents? The answer was actually discovered not by studying humans but peas. Gregor Johann Mendel, an Augustinian friar, crossbred peas with differing characteristics in order to evaluate how different features were inherited in their offspring. His work focused on pea plants and their seven observable traits: the shapes of the pods and seeds; plant height; flower position; and seed, pod and flower colour.

The study took around eight years, in which time he observed some 28,000 pea plants. When looking at the colour of peas produced, Mendel found that different generations of plants expressed different ratios of green and yellow peas, with yellow being the dominant colour. He discovered that genes are paired and the mathematical pattern seen throughout generations caused their dominant and recessive expression. This pattern can also apply to the genetics that code for our eye and hair colour.

Mendel (back row, right-hand side) pictured here with his fellow monks

The generation game

How Mendel discovered genetic inheritance by playing with peas



Parents
Two true-bred plants with opposing physical characteristics (phenotype) were crossbred.

First generation
The first generation of peas expressed the dominant gene of one of its parents.

Second generation
This set of peas displayed a ratio of 3:1, three showing the dominant gene and one expressing the recessive gene.

Self-pollination
After the initial crossbreeding, peas were left to self-pollinate in order to explore a single lineage of genetics.

Rhazes and the hospital trial

Iraq, 10th century

Rhazes was a talented polymath and wrote about many subjects

Abu Bakr Muhammad ibn Zakariya al-Razi, known as Rhazes in the West, was a physician of many talents, including his novel approach in determining the location of a Baghdad hospital.

Under the instruction of the Caliph al-Muktafi to determine where the city's newest hospital should be built, Rhazes used meat to select the right spot. He travelled throughout the city hanging meat in potential locations and left them for a few days. The place in which the meat had experienced the least amount of decay was selected to be the location for the hospital, as he deduced that this was the cleanest area.

"He travelled throughout the city hanging meat in potential locations"

Penicillin is recognised as one of the world's most important advancements in medical history

Fleming's accidental discovery of penicillin

England, 20th century

In 1928, at St Mary's Hospital in London, Alexander Fleming was busy investigating the bacterium, *Staphylococcus aureus.* The bacteria had been wreaking havoc, causing fatal infections, and there was no medicine at the time to treat them.

On one occasion, Fleming forgot to put one of his Petri dishes into an incubator. While he was away on a two-week holiday the bacteria multiplied, and on his return he noticed something unusual in the rogue Petri dish. There was an area where the bacteria could not grow, and instead left a 'mould juice' to form a clear zone around itself. He investigated and found that the mould *Penicillium notatum* had contaminated the dish, inhibiting the growth of the bacteria.

In the late 1930s, scientists Howard Florey and Ernst Boris Chain had managed to isolate and purify penicillin, and the antibiotic was available as an injection by 1941. It is estimated that this discovery has saved up to 200 million lives to date.

The use of penicillin during WW2 helped to save countless lives

Pasteur uncovers the origin of cells

France, 19th century

Back in the 1800s, people thought food spoiled and diseases were caused by 'bad air' or life spontaneously generating. Louis Pasteur didn't – he rejected the idea that mice could be randomly created from rotting wheat and old cloth over a few weeks.

After noticing that his own vats of beer were turning sour, Pasteur started analysing them only to discover they were swarming with bacteria. This convinced him that the spoiling of his brew was caused by these tiny microorganisms. He designed a simple experiment to prove his revolutionary germ theory, and as a result disproved the idea that cells could come from nothing.

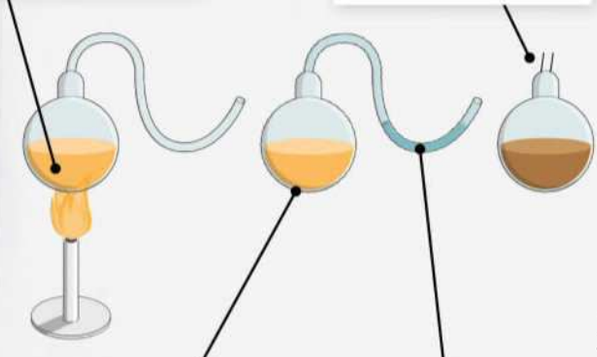
So crucial was his work in the food and medicine industry that we even named a process after him – pasteurisation; the process of heat-treating something for a short time and cooling it down quickly to make it safe from bacteria.

Microbe matters

Armed with a set of swan-neck flasks, Louis Pasteur set out to challenge the status quo

The experiment
Two swan-neck flasks containing liquids filled with nutrients were boiled, to sterilise the liquid.

Straight-neck flask
The open flask allowed air and any bacteria to enter easily. The flask became murky with microbes growing in the liquid.



Success
Pasteur had proved that the organisms were not being spontaneously generated, and that it was the result of germs getting into the flask that causes the liquid to go off.

S-shaped flask
The flask's swan-neck shape meant that condensed liquid pooled in the bend, creating a seal so germs could not enter. The liquid did not change colour or become cloudy.

Marconi's wireless revolution

England, 20th century

We live in a world where we can communicate with almost anyone, anywhere. Amazingly, to do this we don't need to be plugged in. Wireless communication has changed the world.

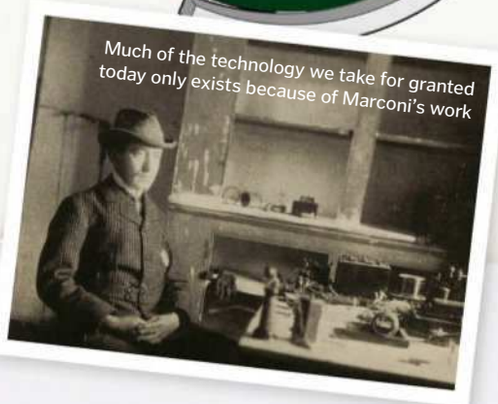
Italian physicist Guglielmo Marconi was a pioneer in telecommunications; influenced by the recent discovery of electromagnetic waves, at the age of just 20 he successfully transmitted a wireless signal over a distance of more than 2.4 kilometres. He was fanatical about invention and wanted to create something practical and commercially successful from this technology.

In 1897, he took to the Salisbury Plains to pitch his workable system to the British government, which involved using an aerial held up by a balloon to improve the range of wireless transmission. When a Morse key was depressed it would cause a spark, which flowed up the antenna and radiated in all directions into space. As it spread through the air a second aerial connected to the receiver would pass over the coherer to complete the circuit and trigger a bell. He demonstrated that he could transmit this signal further than ever before without the need for wires. His next mission: transmit over open sea, and selected Lavernock Point, Wales as the site of the momentous experiment.

Marconi continued to develop the technology, and on 12 December, 1901, he sent the first long-range radio message some 3,380 kilometres across the Atlantic, between Poldhu, Cornwall, England and St John's, Newfoundland, Canada. The basis of all radio communication today had been invented, and though the equipment he used was not new, their organisation was.

"From my earliest experiments I had always held a belief that the day would come when mankind would be able to send messages without wires from between the further most ends of the Earth." How right Marconi was.

Marconi's first Transatlantic radio signal was sent from Cornwall to Newfoundland



Much of the technology we take for granted today only exists because of Marconi's work

Fermi's nuclear reactor

US, 20th century

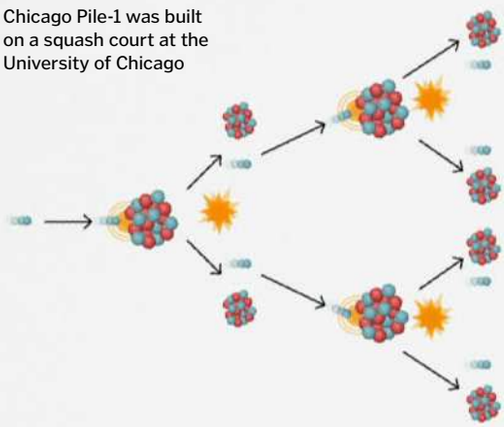
After the atom was split and the term 'nuclear fission' was coined, physicist Enrico Fermi applied the principle to create the first self-sustaining nuclear chain reaction in a human made reactor: Chicago Pile-1.

Scientists were aware that a nuclear reactor would allow for the production of a weapon like nothing seen before. The outbreak of WWII meant that weapon production was a priority, a consequence of which was the birth of both the Manhattan Project and Fermi's reactor.

Once uranium-235 is hit with a neutron, the nucleus splits to form two smaller nuclei and more neutrons, which then go on to split other uranium atoms, thus forming a chain reaction. The reactor was made from stacks of graphite blocks to slow down fast uranium neutrons, increasing the likelihood of nuclear fission.

This reaction needed to be controlled in order for it to be safe. Control rods made from cadmium were used to absorb the excess neutrons created from the nuclear fission. Adding or removing the rods could control the longevity of the chain reaction. This reaction produced large amounts of energy, which could then be harnessed for warfare.

Chicago Pile-1 was built on a squash court at the University of Chicago



"Once uranium-235 is hit with a neutron, the nucleus splits to form two smaller nuclei and more neutrons"

Rutherford strikes gold

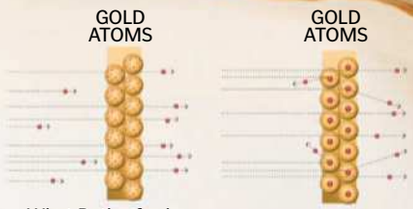
England, 20th century

It was previously believed that the structure of the atom was a sphere of positive charge housing smaller negatively charged electrons within it, like plums within a pudding. To test the accuracy of this 'plum pudding' model — under the direction of Ernest Rutherford — Hans Geiger and Ernest Marsden performed a series of experiments between 1908–1913 to prove Rutherford's theory of an atomic model, which resembled planets orbiting the Sun.

The physicists used a radioactive substance to bombard a thin piece of gold foil with positively charged alpha particles. The majority of particles passed through the foil without any deflection, suggesting that atoms had a great deal of open space. However, some were deflected off the gold foil at different angles, which meant that those particular particles had hit something with the same charge. This meant that rather than a positive charge engulfing electrons, a smaller positive charge was held in the dense middle, thus heralding the discovery of the atomic nucleus.

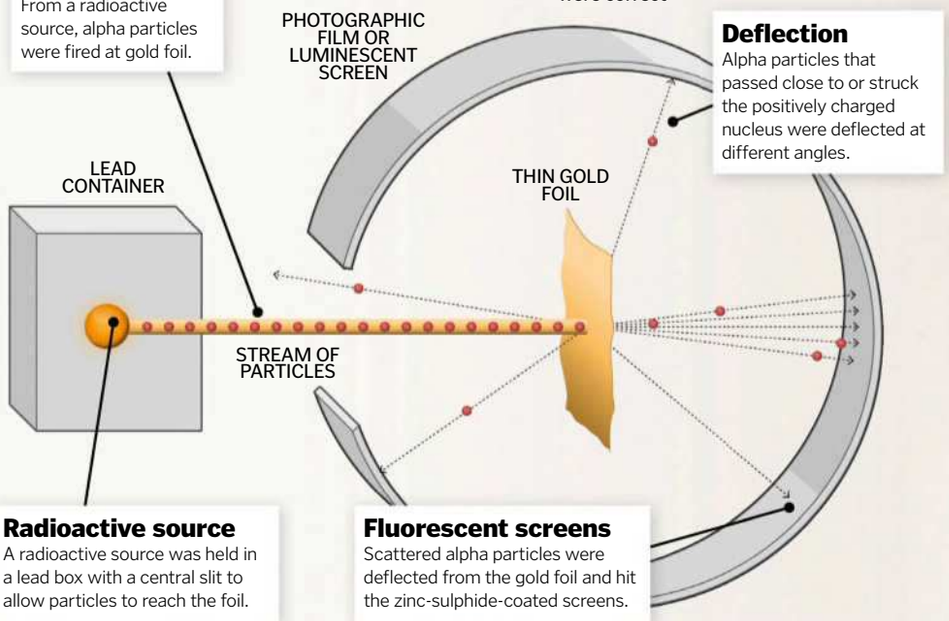
A whole new recipe

The experiment that disproved the plum pudding model



What Rutherford expected if Thomson's model were correct

What Rutherford actually observed



Alpha particles
From a radioactive source, alpha particles were fired at gold foil.

Deflection
Alpha particles that passed close to or struck the positively charged nucleus were deflected at different angles.

Radioactive source
A radioactive source was held in a lead box with a central slit to allow particles to reach the foil.

Fluorescent screens
Scattered alpha particles were deflected from the gold foil and hit the zinc-sulphide-coated screens.

Lavoisier and the conservation of mass

France, 18th century

It was a French chemist named Antoine Lavoisier who formulated the concept of the conservation of mass – the idea that matter can neither be created nor destroyed, only rearranged. He did so by measuring the mass of reactants and products during chemical reactions.

One of Lavoisier's experiments entailed placing a burning candle inside a sealed glass jar. As the wick burned down and the candle melted, the weight of the jar and its contents remained the same, thereby proving his pioneering theory.

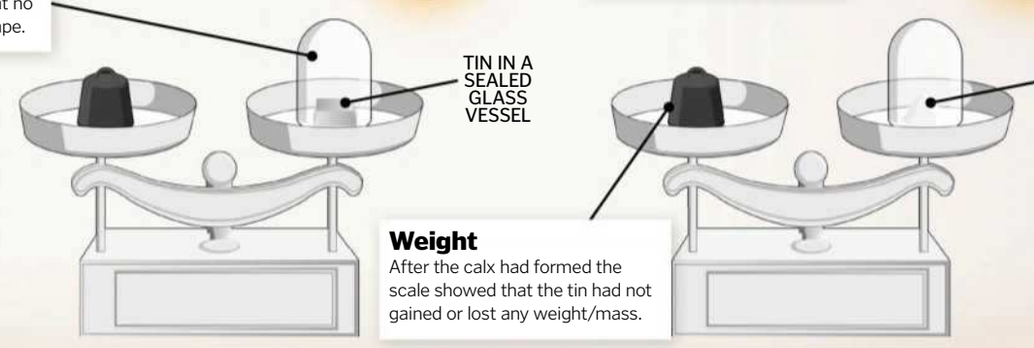
At the time, chemists were exploring the formation of calx (an oxide), predicting that metals lost mass as they were burnt. Lavoisier countered this with the idea that calx was the result of atmospheric gas interacting with the metal. Rather than the metal losing mass, he found it gained weight by combining with oxygen from the air.

Transforming matter

The experiment that changed our understanding of matter without tipping the scales

Heat source
The sealed tin was left to form calx (metallic ash) within the sealed jar, heated by focussing the Sun's rays with a magnifying glass.

Sealed jar
Tin was placed under a sealed jar to ensure that no gas could enter or escape.



Weight
After the calx had formed the scale showed that the tin had not gained or lost any weight/mass.

Lind cures sailors' scurvy

HMS Salisbury, 18th century

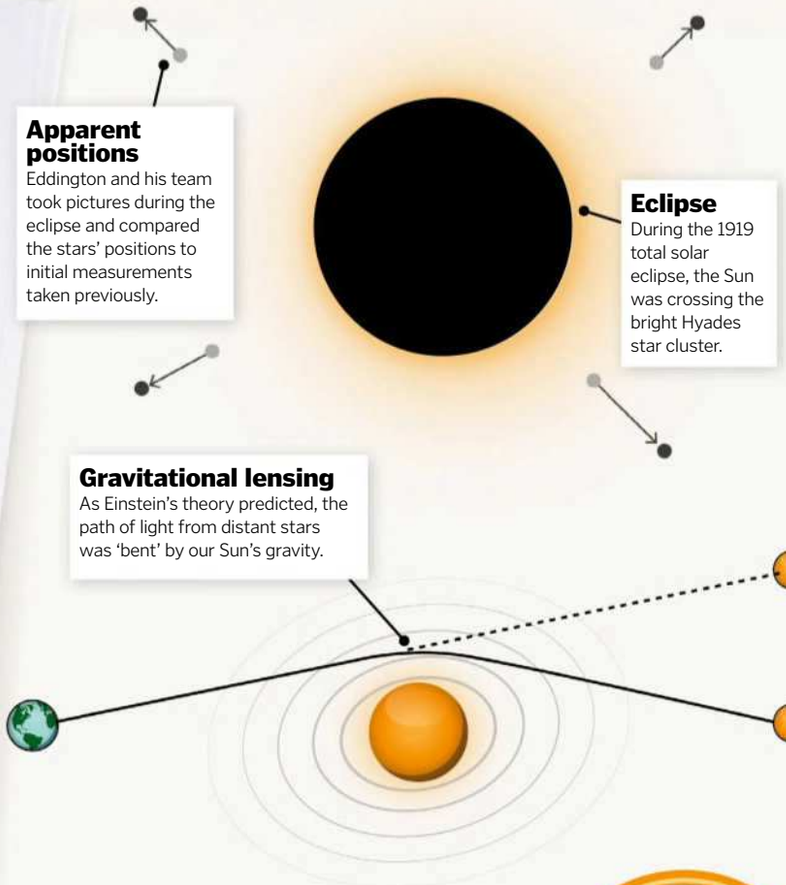
Bleeding gums, your teeth dropping out, weak limbs, swollen legs and nasty patches of blood under your skin – a pirate's life probably wouldn't have been ideal for most of us. Scurvy was one of the diseases that plagued pirates and sailors in the early days of seafaring. We know today that the disease is caused by a serious lack of vitamin C, something we need to form collagen, a vital component in structural and supportive connective tissue. Without enough collagen, the blood vessels and bones of those with scurvy break down until they suffer a slow and painful death. But in the time of Scottish physician James Lind, there was no knowledge about these tiny nutrients. People thought that scurvy might be contagious or caused by madness.

In 1747, Lind started one of the world's first clinical trials. He suspected that acids could help stop the putrefaction of the body, and he devised a trial to test different ways of introducing certain acids into people's diets. He divided a group of 12 scurvy-ridden sailors into six groups of two, all of which were to eat the same diet as one another but with the addition of an acidic supplement.

Each group was treated with either a quart of cider, 25 drops of elixir of vitriol, two spoonfuls of vinegar, half a pint of seawater, two oranges and one lemon, or a spice paste, every day. After six days most of the sailors eating the fruit had made an almost complete recovery. While Lind was on the wrong track about the cause of the disease, he had found the cure.

Scurvy is a disease that people around the world still suffer from, particularly in areas of war or famine

The solar eclipse allowed Eddington to observe how the light from stars is affected by the gravity of the Sun



Eddington and the eclipse

Africa, 20th century

Scientific explanations in theoretical physics often remain just that, theoretical – but not all of them do. Albert Einstein published his general theory of relativity back in 1915, a criteria of which was that light bends near a massive gravitational force. However, Einstein was aware that should this or any of the other criteria required to support his revolutionary idea be disproven, then bang went the theory.

Einstein's pioneering work remained a theory until an astronomer named Sir Arthur Eddington used an eclipse to prove light could be bent by gravitational forces. In order for Einstein's theory to be correct, Eddington had to prove that the light had been bent by a source of intense gravity, such as the Sun. A total solar eclipse in 1919 presented Eddington with a unique opportunity to witness the night sky during the daytime.

After setting sail to Príncipe Island to get the best view of a predicted solar eclipse and test out Einstein's theory, Eddington observed the locations of stars at night and then again under the false night of an eclipse. This meant that he could observe if the gravity of the Sun had altered the stars' apparent positions, which in fact it had. This proved that light had been bent on its journey to Earth by way of the Sun's gravity, meaning Einstein was correct.

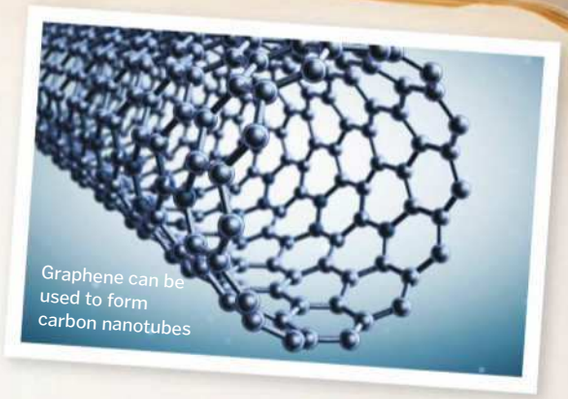
The creation of graphene

England, 21st century

In 2004, Professors Andre Geim and Konstantin Novoselov were experimenting with a graphite crystal. They removed some graphite flakes using sticky tape and, upon closer inspection, realised that some of the flakes were thinner than others.

So they repeated the process, taking off more layers from the original peeled-off flake. Amazingly, their method worked. Each time the flakes were thinner, and they eventually managed to create flakes that were only one carbon atom thick. Although the existence of graphene had been predicted, no one knew how to isolate it. Until now.

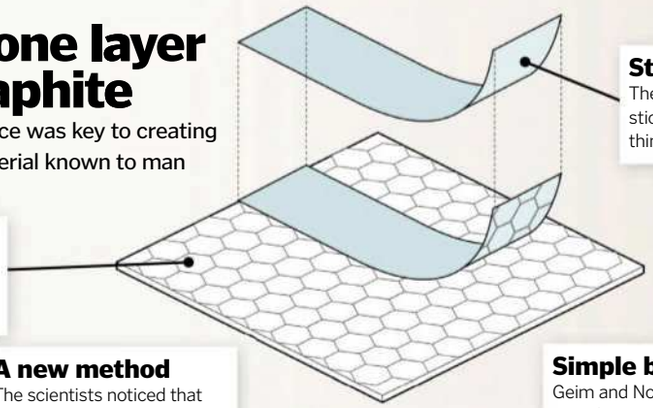
It sounds simple, but graphene has turned out to be a really important material and just what we needed in this digital age for display screens and electric/photonic circuits. A fantastic conductor of heat, dense, lightweight, flexible and transparent, it has been used in everything from tyres to transistors.



Graphene can be used to form carbon nanotubes

Making one layer of graphite

Repetition and patience was key to creating the strongest material known to man

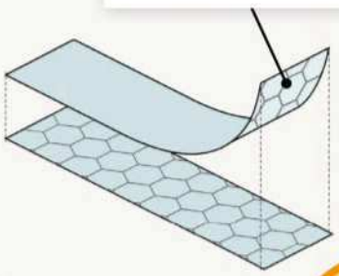


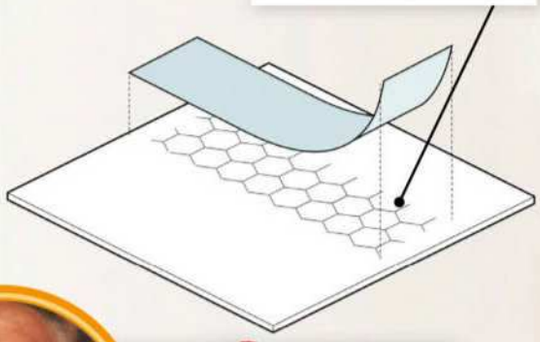
Sticky tape
The scientists used sticky tape to remove a thin layer of graphite.

Graphite
A block of graphite was being used to study the properties of the material.

A new method
The scientists noticed that the flakes were of different thickness. They decided to investigate, repeating the process, over and over again.

Simple but effective
Geim and Novoselov transfer the sample onto a silicon surface, successfully isolating graphene.





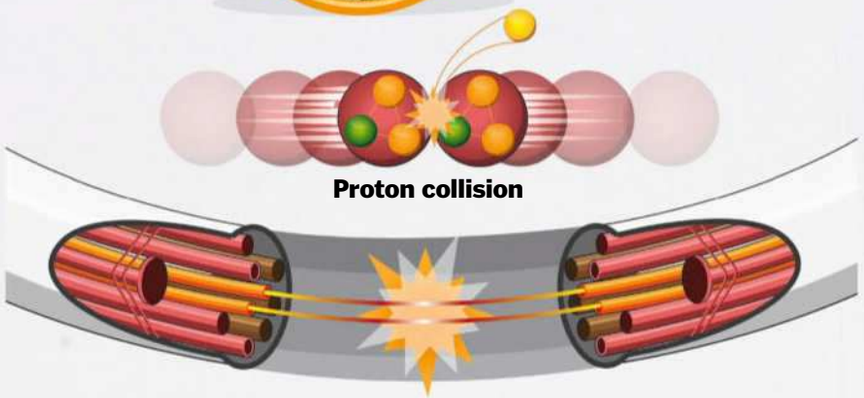
> *"Graphene has turned out to be a really important material in this digital age"*

From theory to reality

Switzerland, 21st century

In 1964, particle physicist Peter Higgs proposed a theory as to how particles have mass. He suggested that empty space is occupied by a field termed the Higgs field, where particles pass through it and either collect mass, like an electron, or don't interact with it at all and remain massless, such as a photon. An analogy would be a person moving through a crowd of strangers versus a crowd of friends.

Moving through of crowd of strangers, you would pass easily without stopping, whereas surrounded by friends you might stop to talk, taking you longer to make your way through. In this case your friends would be the Higgs boson. The Large Hadron Collider fires two beams of protons in opposite directions and accelerates them to near the speed of light so they collide to release the boson and other subatomic particles. This became a reality on 4 July 2012.



Higgs received the Nobel Prize in Physics in 2013 for his theoretical discovery

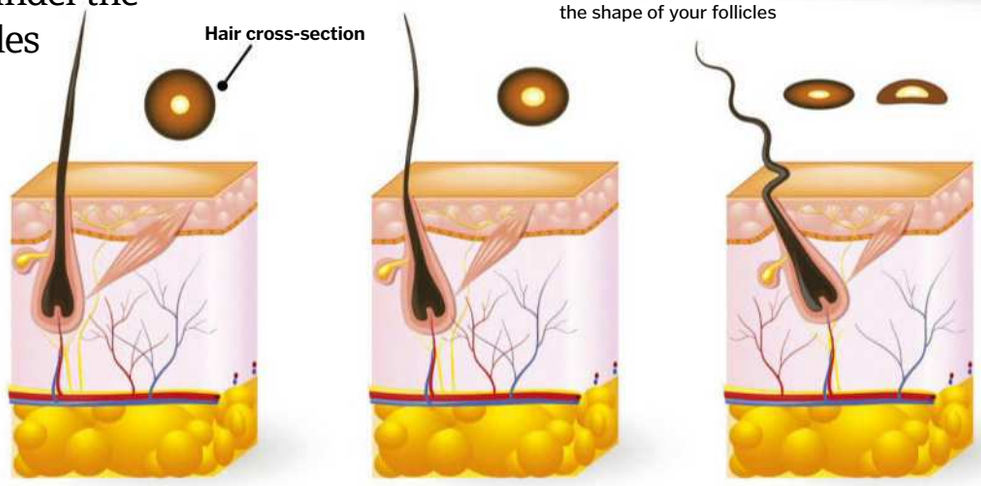
What makes hair curl?

The secret to tousled tresses lies under the skin in the shape of the hair follicles

Your hair type depends on the shape of your follicles

Hairs might look similar from the outside, but put them under the microscope and you'll notice tiny differences in shape. Straight hair is perfectly round in cross section, while curly hair is oval or D-shaped. The strands flex more easily in one direction than the other. If the shape varies along the length of the hair it will tend to twist. If it flips back and forth the hair will crimp or kink. And if the turns are regular it will make waves.

These patterns are determined by the hair follicle itself. A look beneath the skin reveals that straight hair follicles are straight and curly hair follicles are S-shaped. In the straight follicles, all the cells work together to make a symmetrical hair, but in curly follicles everything is asymmetrical.



Straight hair
Straight hair is circular in cross section and the follicles are straight.

Wavy hair
Wavy hair is slightly flattened and the follicles aren't perfectly straight.

Curly hair
Curly hair is oval or D-shaped and the follicles bend into an S.

Why our ears pop

How do changes in pressure make our hearing go funny and our heads feel full?

The change in pressure during take-off and landing can make your ears pop

The middle ear separates the outer ear from the inner ear. It contains the three ear bones, which send vibrations from the eardrum towards the fluid inside the cochlea. The pressure in the middle ear needs to be the same as the pressure in the outside world, otherwise the eardrum can't vibrate properly.

Air is constantly leaking out of the middle ear and into the tissues. To keep it topped up the eustachian tube, which runs from the middle ear to the back of the nose, opens and shuts to let air through.

If the pressure changes suddenly, the air inside the middle ear contracts or expands, pushing or pulling on the eardrum. To pop the ears back to normal you just need to open the eustachian tubes to equalise the pressure. Try swallowing, yawning or chewing.

Eardrum
When the pressure in the middle ear changes, the eardrum bulges inwards or outwards.

Middle ear
Ears pop when the pressure in the air-filled middle ear doesn't match the pressure outside.

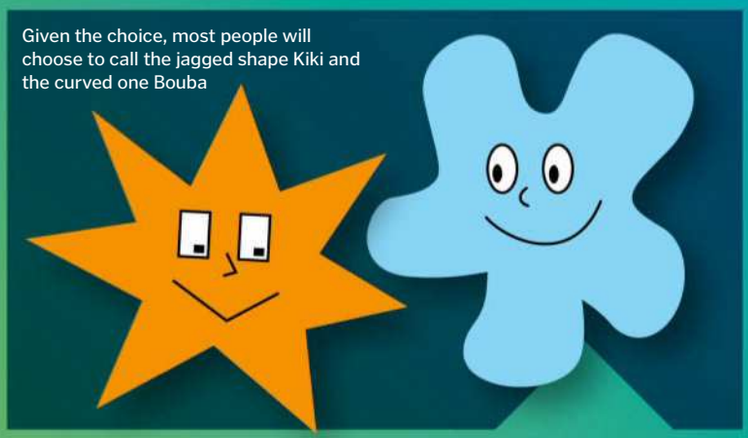
Eustachian tube
This tube connects the middle ear to the nose. Opening it helps to balance the pressure.

Ear anatomy

The middle ear is full of air and sensitive to changes in pressure

What's in a name?

The biology, psychology and sociology of your name may be influencing you more than you realise



Given the choice, most people will choose to call the jagged shape Kiki and the curved one Bouba

Humans have an innate preference for naming shapes

If you look at the characters above, which would you give the name 'Kiki' and which one would you name 'Bouba'? Chances are you answered the same as the majority of other people reading this magazine. This is because the brain attaches abstract meanings to shapes, a phenomenon that appears consistent across languages.

Scientists think the reason we do this is because the rounded shape our mouth makes when we pronounce Bouba is associated with similar shapes, while we form angular shapes with our mouths when we pronounce Kiki. Research suggests that we associate names like Rose with softer facial features, whereas we might associate Max with more angular features.

The theory that names can influence our life choices is called nominative determinism

It might not be a coincidence if you know a Mrs Read who is a librarian

Usain Bolt set a world record of 9.58 seconds for the 100-metre sprint at the Berlin 2009 World Championships. Even his name sounds fast – Bolt. This isn't the first time we have seen a pattern between a career and an individual's name. Other examples include Sue Yoo, an American lawyer; Dr Michael Docktor of Harvard Medical School; and Scott Speed, a NASCAR racing driver. Researchers think this may be more than humorous coincidence.

It's thought that someone's self-image could be determined by their name, or their name might cause expectations among their peers that they take on board. There could also be a genetic explanation; names originating from a career, such as Fisher and Butcher, may be passed on along with the corresponding genes that make their owners suitable for the job.

Those with easily pronounced names are more likely to receive votes in elections and even tend to be higher up within companies

People with easier-to-pronounce names are seen more positively

Experiments that analyse the results of hypothetical elections suggest that we react more positively to names that are easy to pronounce. Studies have also found that lawyers in the US with easy-to-say names tend to hold higher positions. Interestingly, the results were not affected by how familiar a name was to the individual judging the candidate, nor the perceived ethnicity of the surname.

This phenomenon stems from the human brain's preference for things we find easy to understand. Reading these names causes feelings of positivity, which means we judge people more kindly. This means surnames such as Evans, Ali or Depp tend to be judged more positively than names like Schwarzenegger, LaBeouf or Cumberbatch.

We say men and women's names differently

Researchers at Columbia University, US, have reported that female and male names are phonetically different. Place your fingers on your throat. Can you feel the difference when you say 'Sophie' compared to 'Thomas'? Male names are generally pronounced as harder-voiced sounds, while female names are softer, unvoiced sounds with less vocal cord vibration. It's thought that these differences are the result of gender stereotyping.

There is a tendency in many languages for 'female' names to end in vowel sounds

Simply using middle initials can influence how people react to an author's work

Middle initials matter

Dr Wijnand A P van Tilburg and Dr Eric R Igou conducted studies at the University of Limerick to investigate if middle names matter. In a series of experiments students from the university were given extracts from academic texts. Some were given texts written by an author who was listed without a middle name, while others were given pieces penned by an author who had one or more middle names. The latter was interpreted consistently as more prestigious and of a higher standard.

THE SCIENTIFIC FACTS BEHIND THE HEADLINES

Learn the truth behind the biggest health and body myths of our times and discover what is really going on inside your body when you eat, drink and exercise.

ON SALE NOW

FUTURE

Ordering is easy. Go online at:

www.myfavouritemagazines.co.uk

Or get it from selected supermarkets & newsagents

Cleaning the blood

Dialysis machines are artificial kidneys, keeping the blood clean when the kidneys fail

The kidneys have lots of jobs, but one of the most important is keeping the blood clean. Packed inside these bean-shaped organs are hundreds of microscopic filter systems. Blood passes in through the renal arteries at high pressure, rushing into balls of leaky blood vessels. Fluid and waste squeeze out of the bloodstream and into tiny tubes called nephrons. As the fluid passes through these tubes the body reabsorbs useful molecules. The rest forms urine and is removed via the bladder.

This system is sensitive to damage. High blood pressure, diabetes and recurrent infection can stop the filters working. Should this happen then dialysis can take over the job, allowing the kidneys to heal or keeping the blood clean until a transplant becomes available.

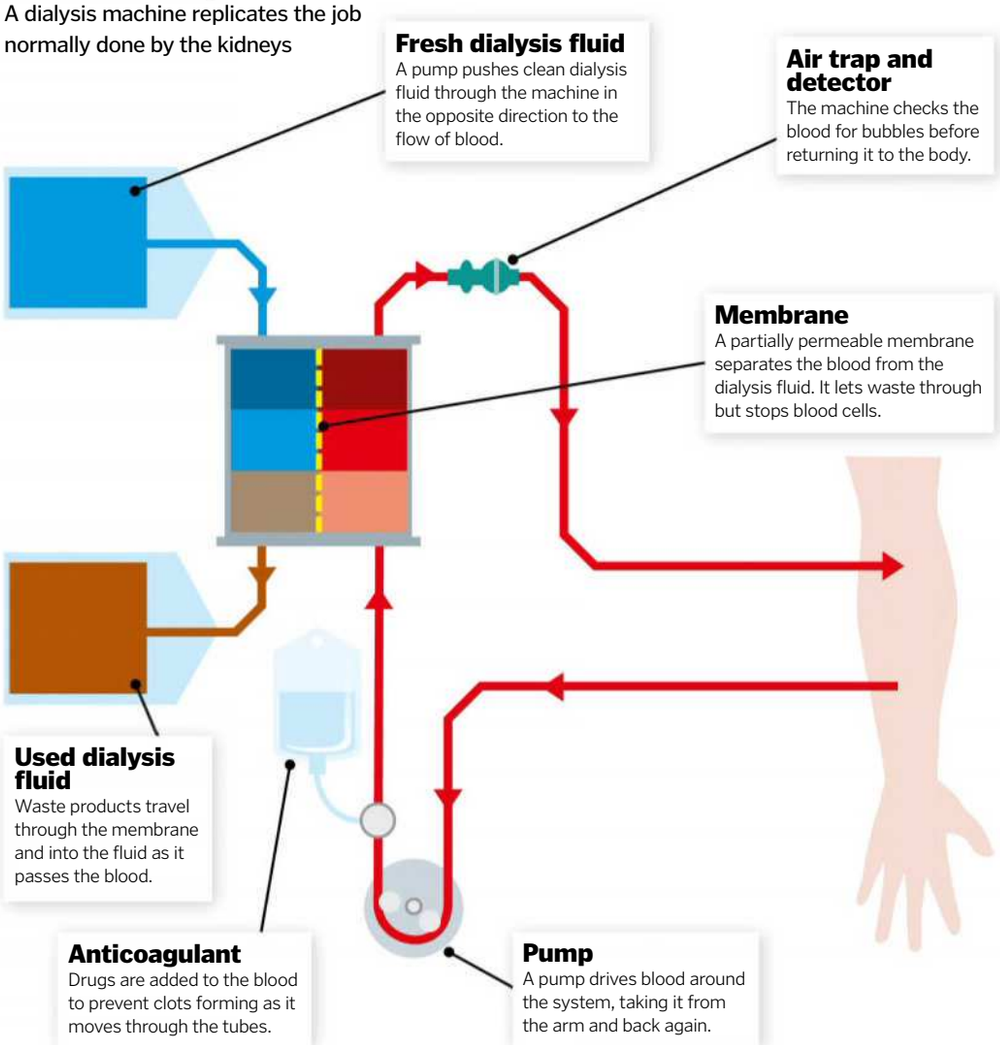
First, doctors widen the blood vessels in the arm by creating an arteriovenous fistula, or by implanting a graft. This joins an artery to a vein, allowing blood to flow quickly in and out of a haemodialysis machine. These machines are essentially artificial kidneys, and they clean the blood in almost the same way.

Blood enters the machine and passes over a semi-permeable membrane. Dialysis fluid passes in the opposite direction on the other side. The concentration of waste is higher in the blood than it is in the fluid, so the molecules diffuse across. However, the holes in the membrane are too small for blood cells, so they remain in the bloodstream and return to the arm. The whole process takes around four hours and patients need to repeat it three times a week.

The machine cleans the blood as it moves out of the arm and back again

How dialysis works

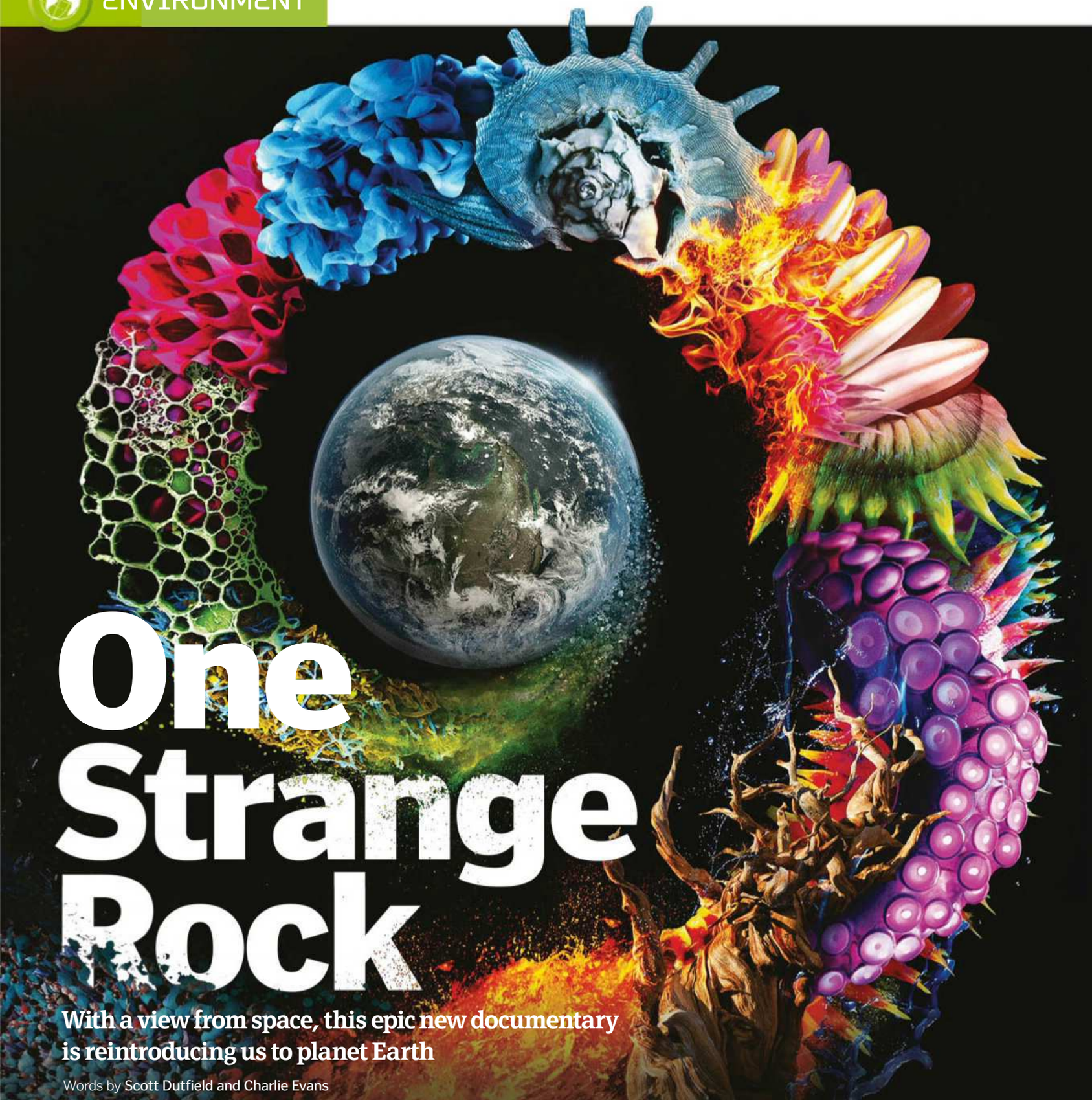
A dialysis machine replicates the job normally done by the kidneys



Peritoneal dialysis

Passing blood through a machine isn't the only way to clean out toxins. Dialysis works by drawing chemicals out of the blood, through a membrane and into waste fluid, and this is possible inside the body too. The peritoneum is the membrane that lines the abdominal cavity around the digestive organs. It has lots of blood vessels and can work as a dialysis filter. To set this up, doctors place a small tube, or catheter, near the belly button, allowing dialysis fluid to enter the belly. As blood travels through the peritoneum, waste products pass across the membrane and into the fluid. The fluid can then be drained away, taking the waste out of the body with it. Peritoneal dialysis happens between four and six times a day, and people can do the fluid exchange by hand in their own homes.

Fluid enters the abdomen through a catheter near the belly button



One Strange Rock

With a view from space, this epic new documentary is reintroducing us to planet Earth

Words by Scott Dutfield and Charlie Evans

Our planet is full of weird and wonderful scenes, from lakes filled with acid to vast rainforests teeming with life. Viewing these wonders is awe-inspiring from the surface, but when you can see it from the vast expanses of space the spectacle can be life changing.

One Strange Rock follows the stories and insights of eight astronauts who can share an outsider's view of our planet. Joined by the Fresh Prince himself – Will Smith – as host, this team of astronauts perfectly illustrate the delicate yet intertwined processes that keep our planet in balance. "There is absolutely nothing on one side of the planet that isn't connected in some way to the other" observes Space Shuttle and International Space Station veteran, Nicole Stott.

The documentary highlights how events billions of years ago resulted in the finely tuned natural processes of today, from the oxygen cycle to the development of a magnetic field defending the Earth from the Sun. We are taken on a journey to the strangest and most spectacular parts of Earth in a quest to understand what makes us unique.

Seeing the world from space has allowed humankind to witness the truly strange rock we live on like never before.

The deadly Dallol

Discover the barren wasteland bubbling with lakes of acid

As a team of astrobiologists trek over the crumbling deposits of an acid lake, dressed head to toe in their hazmat suits, it becomes clear this place is hostile to humans.

Located within the Danakil Depression in Ethiopia, Dallol averages a year-round temperature of around 34 degrees Celsius, and its acidic plains only receive between 100–200 millimetres of rainfall per year. Its colourful appearance mostly comes from dissolved salts, sulphur and potassium brought to the surface thanks to the magma heating the groundwater. On the surface, the beating Sun evaporates the moisture, leaving behind the vivid yellow, red and green salts.

As inhospitable as it appears – the air is also toxic – there are some signs of life in the pools. Dr Felipe Gómez Gómez and his team brave the dangers of the acid to collect samples containing the only locals, bacteria that can withstand the harsh environment without the need for oxygen. Known as polyextremophiles, these acid-loving bacteria are adapted to live in high-temperature acid. Should the world ever be devoid of oxygen, the Dallol might be an indication of an acidic alternative.

Dallol is one of the hottest places on Earth, regularly reaching 45°C

Acid dominates the barren lands of Dallol, resulting in the formation of toxic salts

Will Smith is the narrator and presenter of this epic new series

Amazon watchtower

Taller than the Eiffel Tower, this observatory keeps an eye on the rainforest below

Commenting on the intricacies of the simple air we breathe, *One Strange Rock* reveals the importance of water crossing the Amazon. Towering above the treetops of the Amazon Rainforest is a structure designed to observe the forest from a different perspective. Known as the Amazon Tall Tower Observatory (ATTO), this structure is the tallest in South America, reaching 325 metres in height. This enables researchers to monitor any changes in the temperature, atmosphere and the 'lakes' of clouds passing overhead. As water evaporates from the lush vegetation, vast clouds form in the skies above, transporting water across the forest and beyond.

Climatologists use ATTO to monitor the health of the forest below

The water from aquifers is filtered through the forest vegetation and eventually released, helping to form clouds

A bat bonanza

Flocking in their millions, these migrating bats gather in the pursuit of fruit

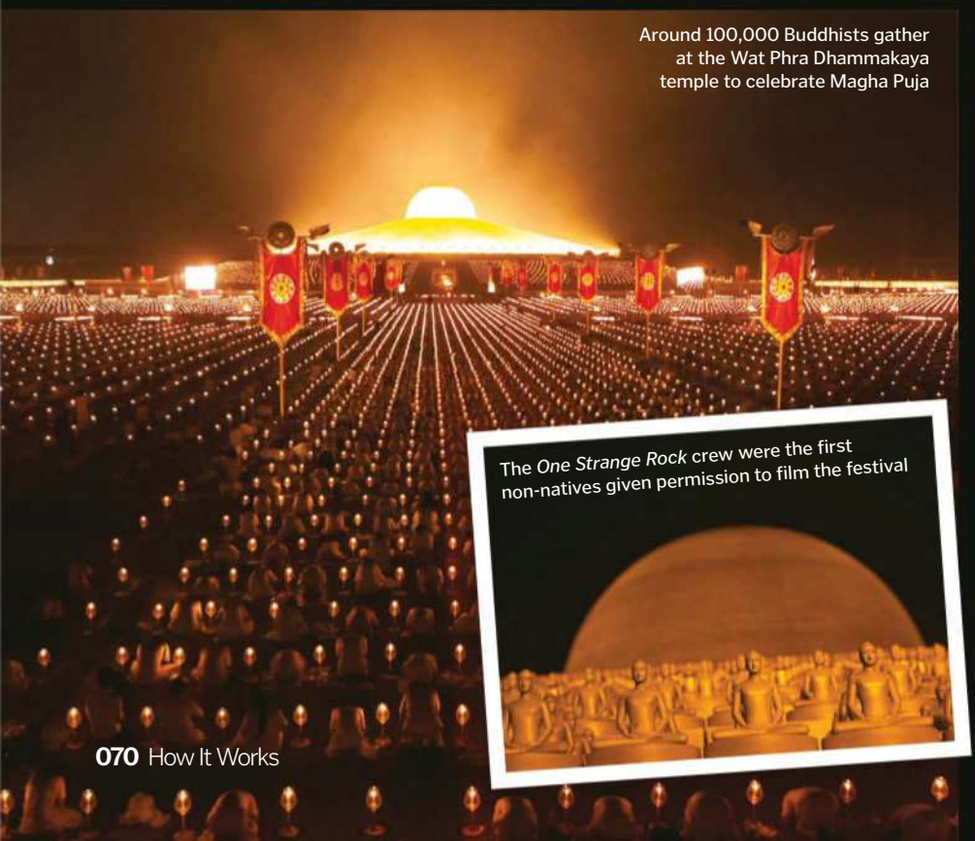
It might seem like quite a jump to go from our planetary twin crashing into Earth to the wondrous scene of migrating bats, but what this documentary does so well is showcase the interconnectivity of all the events our planet has experienced. This phenomenon is no exception.

Every year, around 10 million straw-coloured fruit bats make the journey across Africa – the largest migration of its kind on the planet – their flight ends with them covering an area of around 26,000 square kilometres. Their destination is the region of Kasanka, Zambia, a land with a plentiful supply of fruit for these flying mammals to gorge on.

Consuming around half their body weight in fruit each night, these bats collectively eat around 1,000 tons' worth. Within each fruit there are seeds, which are spread in the bats' waste, helping new life to begin.

"Our planet works in harmony, generating a global ecosystem"

The bats migrate to a swamp forest inside Kasanka National Park



Around 100,000 Buddhists gather at the Wat Phra Dhammakaya temple to celebrate Magha Puja

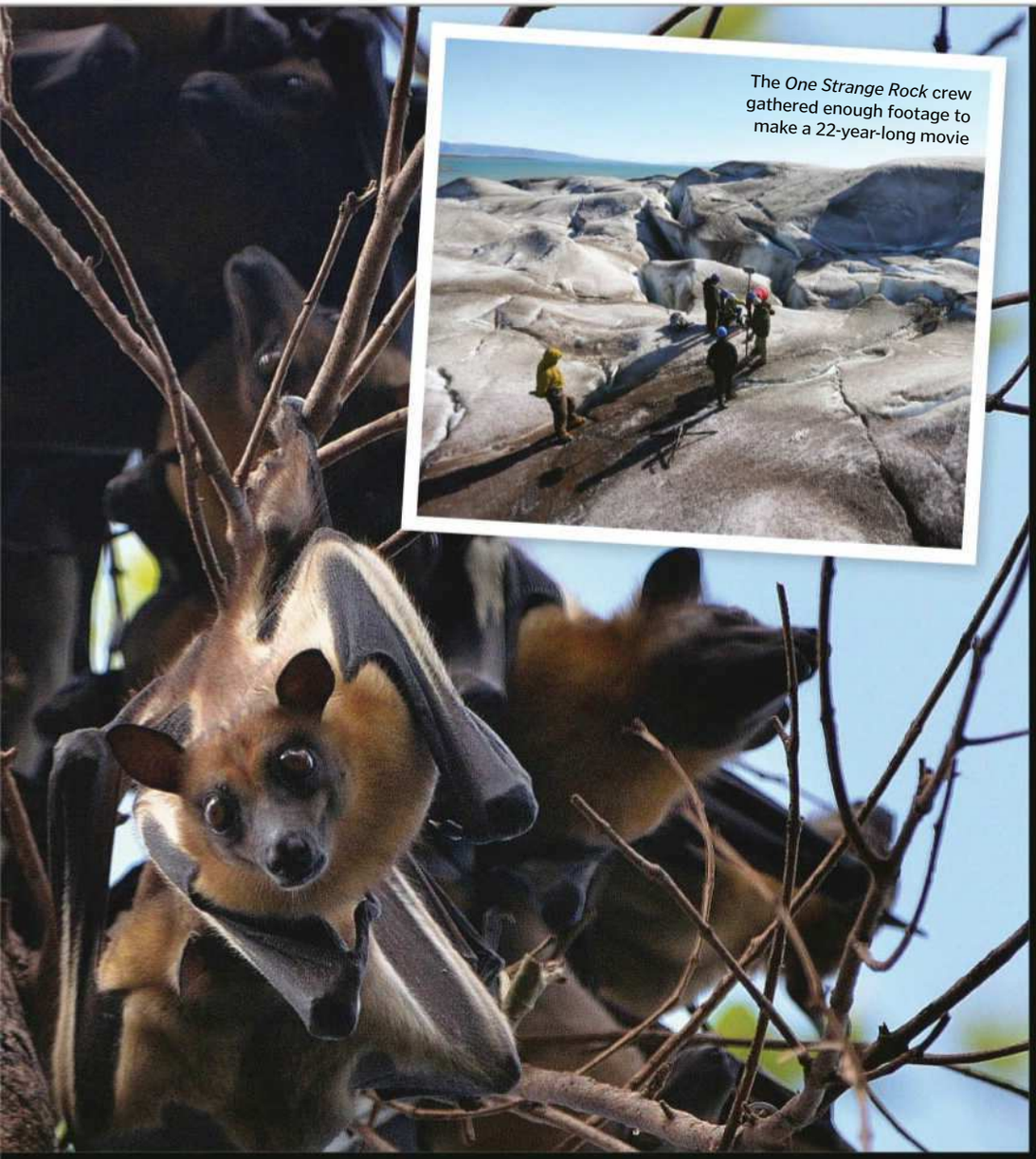
The *One Strange Rock* crew were the first non-natives given permission to film the festival

Magha Puja festival

Buddhists gather under the full Moon to celebrate the equilibrium of Earth

The systems of our planet work in harmony, generating a global ecosystem that is precise and cohesive, but most importantly balanced. This natural equilibrium is what the Buddhists of Thailand celebrate annually.

In the third lunar month, the Magha Puja festival is celebrated en masse at the breathtaking Dhammakaya Cetiya in Pathum Thani, which at night basks in the light of thousands of candles. The festival celebrates the day the teachings of the Buddha were delivered to 1,250 disciples, who spontaneously gathered to be ordained, around 2,600 years ago under the light of the full Moon.



The *One Strange Rock* crew gathered enough footage to make a 22-year-long movie

Our strange world in numbers

27 MILLION TONS

of Saharan sand falls on the Amazon Rainforest each year

The Amazon Rainforest is

10x

the size of Texas

Diatoms are

4x

thinner than a human hair

640,000km

The approximate distance the Earth's magnetic field extends into space

400 MILLION YEARS AGO

simple vertebrates took their first steps on land

Humans pump

60x

more carbon dioxide into the air than volcanoes

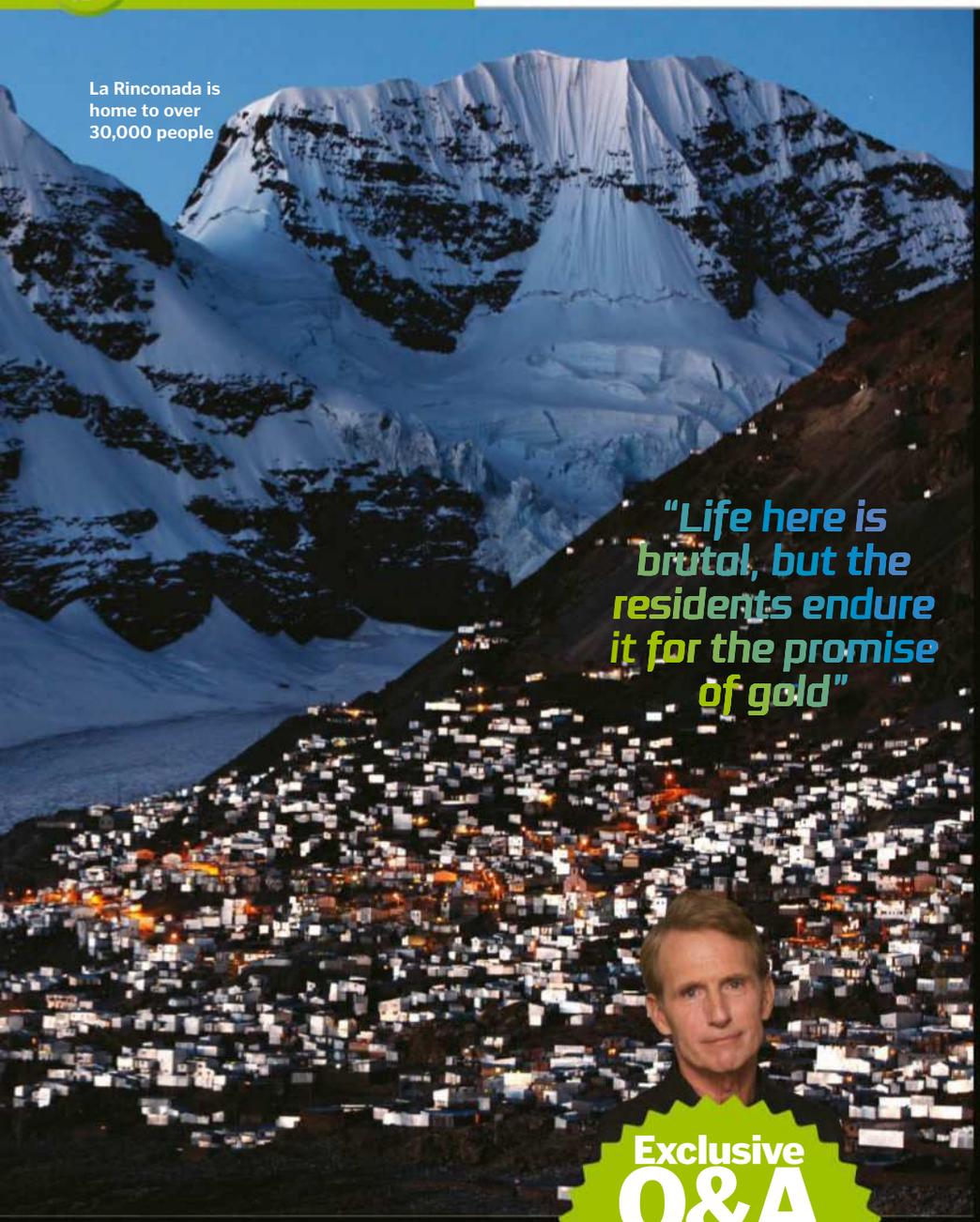
16

The amount of breaths you take every minute

4.5 BILLION YEARS AGO

a Mars-sized rock collided with Earth

The astronaut stars of *One Strange Rock*, from left to right: Mike Massimino, Nicole Stott, Jeff Hoffman, Peggy Whitson, Jerry Linenger, Leland Melvin, Mae Jemison and Chris Hadfield



La Rinconada is home to over 30,000 people

"Life here is brutal, but the residents endure it for the promise of gold"

Life at the extremes

How the quest for gold created the world's highest settlement

High above the rest of civilisation, precariously clinging to the side of a mountain in the Peruvian Andes, the small community of La Rinconada battles against the cold, mercury exposure and low oxygen levels. Life here is brutal, but the residents endure it for the promise of gold – the opportunity to find an elusive precious metal that could see them to a better future.

At some 5,100 metres above sea level, the community here lives at a higher altitude than any other permanent settlement in the world. At 3,000 metres above sea level, humans feel the effects of altitude sickness. Our planet's gravity pulls oxygen close to the surface, meaning the air is thinner the higher we travel. The thin air makes it almost impossible to breathe efficiently, so the community of La Rinconada chew on the gritty, bitter leaves of coca to relieve the symptoms of pain and fatigue, helping them continue to work.

The gold the locals hunt for can either be found deep inside the glacier within the rock, or among the discarded stones between the makeshift football pitches, playgrounds and corrugated iron houses. But to separate the rock from the precious gold is a dangerous process causing serious health and environmental effects. The ore is mixed with mercury, to form a gold-mercury amalgam. This is then heated to leave pure gold in the pan but toxic fumes are spread throughout the town, which also contaminates the nearby water supply.

Exclusive Q&A

Head to **howitworksdaily.com** to read our interview with astronaut **Jerry Linenger**

The Theia impact

The Moon became Earth's satellite after a catastrophic collision

The Moon is the closest celestial object to us, and its gravitational pull influences our planet's tides. But it hasn't always been there. Scientists hypothesise that the Moon resulted from an impact with a Mars-sized planet called Theia around 4.5 billion years ago. The cosmic crash hurled vaporised chunks of the crust into space and centred near the Earth's elliptical plane, entering orbit around us. The evidence is compelling, because the spin of Earth and the orbit of the Moon are similarly oriented, and the Moon contains a relatively small iron core like our planet.

Studies of lunar rock samples taken during the Apollo missions support the Theia impact hypothesis

There are over 6,000 cenotes in Yucatán

The series covers the events that shaped our planet and all life upon it

Yucatán cenotes

Some of the most beautiful natural phenomena on Earth mark the site of an asteroid impact

The Ring of Cenotes in Yucatán, Mexico, is famous for the incredible beauty of its azure pools of water, but this semicircle of sinkholes also reveals some secrets of our planet's past.

When viewed from above, the cenotes mark out a 180-kilometre-diameter arc, coinciding with the impact crater of the dinosaur-destroying asteroid that struck 66 million years ago.

The Yucatán Peninsula was once a reef covered by an expansive ocean. As plants and animals died in the water, layers of sedimentary rock built up on the ocean floor. Over time and under great pressure they were solidified into limestone rock. When sea levels dropped during the Ice Age the reef died, leaving the exposed rock to form the floor of a jungle.

Today, the 1.6-kilometre-thick soft rock has been eroded, and the caves have been flooded with water. Divers from around the world come to explore the caves and tunnels of water among the fossils of the ancient reef.

Our magnetic field extends from Earth's core out into space

Earth's shield

Our protective magnetic field is generated deep within the planet

A compass points north because our planet has a magnetic field. Scientists expect that this is being generated from deep within the core of the Earth, beneath the layers of molten metal swirling beneath our planet's crust.

Thousands of kilometres beneath our feet, at the centre of the Earth, sits a solid inner core encased by a liquid mantle. This inner core is a ball of solid (mainly) iron metal, and as the iron atoms can overlap, the electrons within its outer shells are free to move within an electron 'sea'.

The inner core is about 5,430 degrees Celsius – as hot as the surface of the Sun; it is solid because of the crushing pressure. It heats the lower part of the liquid outer core, creating convection currents as the cool, dense material sinks and the lighter material rises, cools and sinks again, causing constant movement. It is this movement that is thought to generate our magnetic field.

The Ozone layer

Our survival depends on the thin blue bubble of gases that envelopes our strange rock

The early oceans over 2 billion years ago didn't look very impressive. There were no shoals of fish, no pods of whales, no towering forests of kelp. But beneath the surface of the water, the seas were teeming with microscopic life. These primitive aquatic organisms had the ability to harness the power of the Sun and convert molecules of water and carbon dioxide into molecular oxygen (O_2). Across the 200 billion known galaxies containing countless stars and planets, our world is the only place in the universe where we know this can occur.

The tiny cyanobacteria filled our young Earth with oxygen and reduced the levels of carbon dioxide. This not only enabled new life to evolve but gave our planet a protective layer of gas known as the ozone. High up in the early atmosphere, some oxygen molecules absorbed the Sun's ultraviolet rays, splitting to form single oxygen atoms (O), which combined with the molecular oxygen (O_2) to form ozone (O_3).

The layer filtered out the dangerous solar rays and protected life on Earth from being fried by harmful radiation. This meant that life could finally move out of the water – fins slowly evolved into legs, gills became lungs, and life colonised land for the first time, paving the way for an evolution explosion.

The average thickness of the ozone layer is just 3mm

Above and below: the *One Strange Rock* crew conducted 139 shoots on every type of terrain

From stardust to strange rock

How our unique planet formed

4.6 billion years ago (BYA)
A cloud of stardust collapses, creating a disc of material around it.

Lighter elements
Solar winds sweep away the hydrogen and helium from the centre of the collapsed dust cloud.

Planets start to form
Clumps of material continue to collide and grow, making even bigger spheres, which will eventually become the planets.

Aggregation
Stardust left over from the cloud starts to clump together due to the Sun's gravity.

4.54 BYA
The remaining heavy materials form smaller rocky planets. One of these planets will become Earth.

4.54 BYA
Earth's rocky core forms first as the heavy elements collide, bind, and sink to the centre, while the lighter materials form the crust of our planet.

The Sun forms
The immense pressure causes hydrogen atoms to fuse into helium in the centre of the collapse, releasing a huge amount of energy.

3.8-3.5 BYA
As the Earth cools below 100°C, most of the water vapour condenses and forms the oceans. The cooler, calmer planet and the presence of water enables the development of unicellular life.

4.5 BYA
Young Earth suffers a huge collision with an object known as Theia, which causes pieces of the mantle to hurtle out into space. These pieces are pulled together and fused under great pressure to form our Moon.

Early atmosphere
Gravity catches some gases during Earth's formation to create the planet's first atmosphere. It was mostly carbon dioxide with little or no oxygen, and small amounts of water vapour, ammonia and methane.


Bird lungs are small and rigid, but they are aided by expanding air sacs

How birds breathe

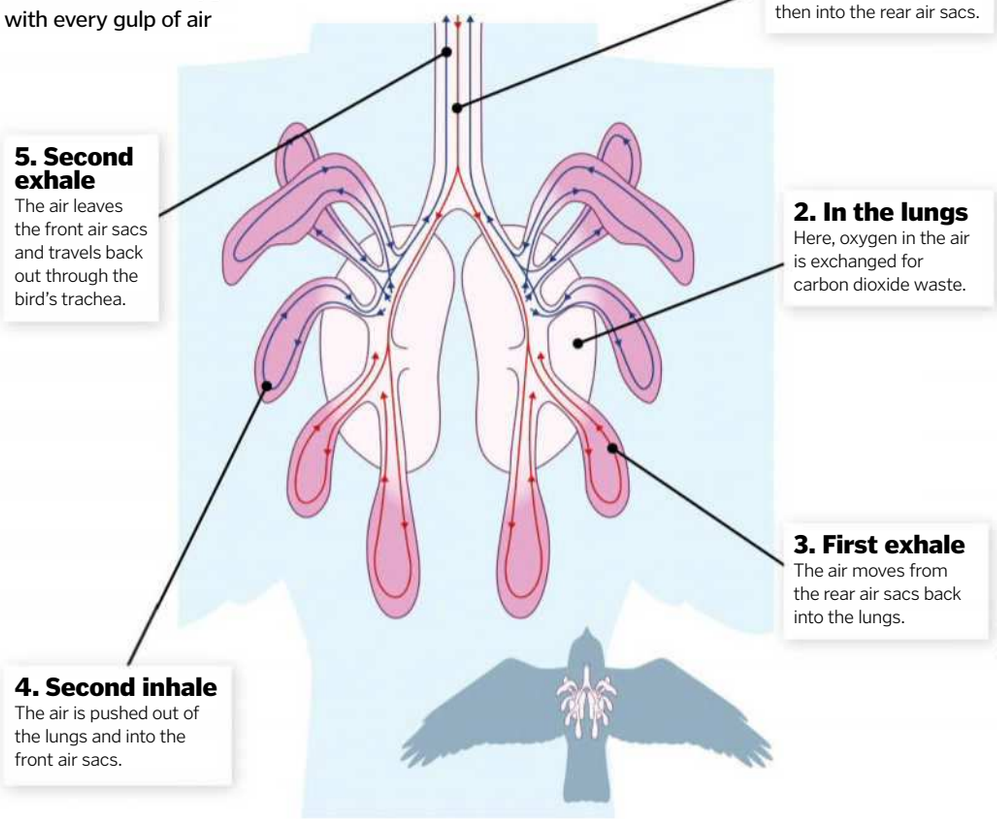
Discover the unusual respiratory system that helps birds fly the distance

When mammals breathe, air travels into the lungs and then back out again in a single breath, providing only one chance to transfer its oxygen into the blood. Birds, however, take two breaths to process one lot of air, meaning it passes through the lungs twice for a double dose of oxygen.

This efficient method of respiration is the reason birds are able to fly long distances despite their small lungs. The lungs get help from air sacs – most birds have nine – that work like bellows to pump air through the lungs. These sacs also regulate their body temperature and help aquatic birds to float on water.

Air efficiency

A double dose of oxygen with every gulp of air



Creative creatures

Meet the amazing animals that have learnt to use tools

Chimpanzees
Chimps can adapt twigs to fish termites from their nests and absorb water to drink from narrow holes in trees. They also use rocks as weapons and to hammer open nuts. Some have even been seen crafting spears.

Crows
Certain species of crow have been observed using sticks to extract food and transport it back to their nests. They even seem to develop a fondness for particular tools, with hooked twigs often a favourite.

Tusk fish
As revealed on *Blue Planet II*, this clever species of fish has worked out how to smash open clams on pieces of rock or hard coral in order to get to the juicy food within, a process that can take minutes or hours.

Crocodiles
In a first for reptiles, crocodiles have been observed balancing sticks on their snouts to lure unsuspecting birds looking for nest-building materials into their reach, so that they can eat them.

Octopus
These soft-bodied molluscs use coconut shells and other such debris that they find on the sea bed as protective armour, hiding inside as a predator approaches and then rolling away when it swims off.

Creating cotton

How is the cotton plant turned into the clothes in your wardrobe?

Cotton is one of the world's most versatile crops as its soft fibres can be made into a wide range of useful products. It grows in the dry regions of the tropics and sub-tropics of Africa, Asia, Australia and America and is used all over the world to make clothing, home furnishings and many more items we use every day. Its usefulness has been known about for thousands of years; there is evidence that people in Asia and South America began growing cotton crops as far back as 3000 BCE.

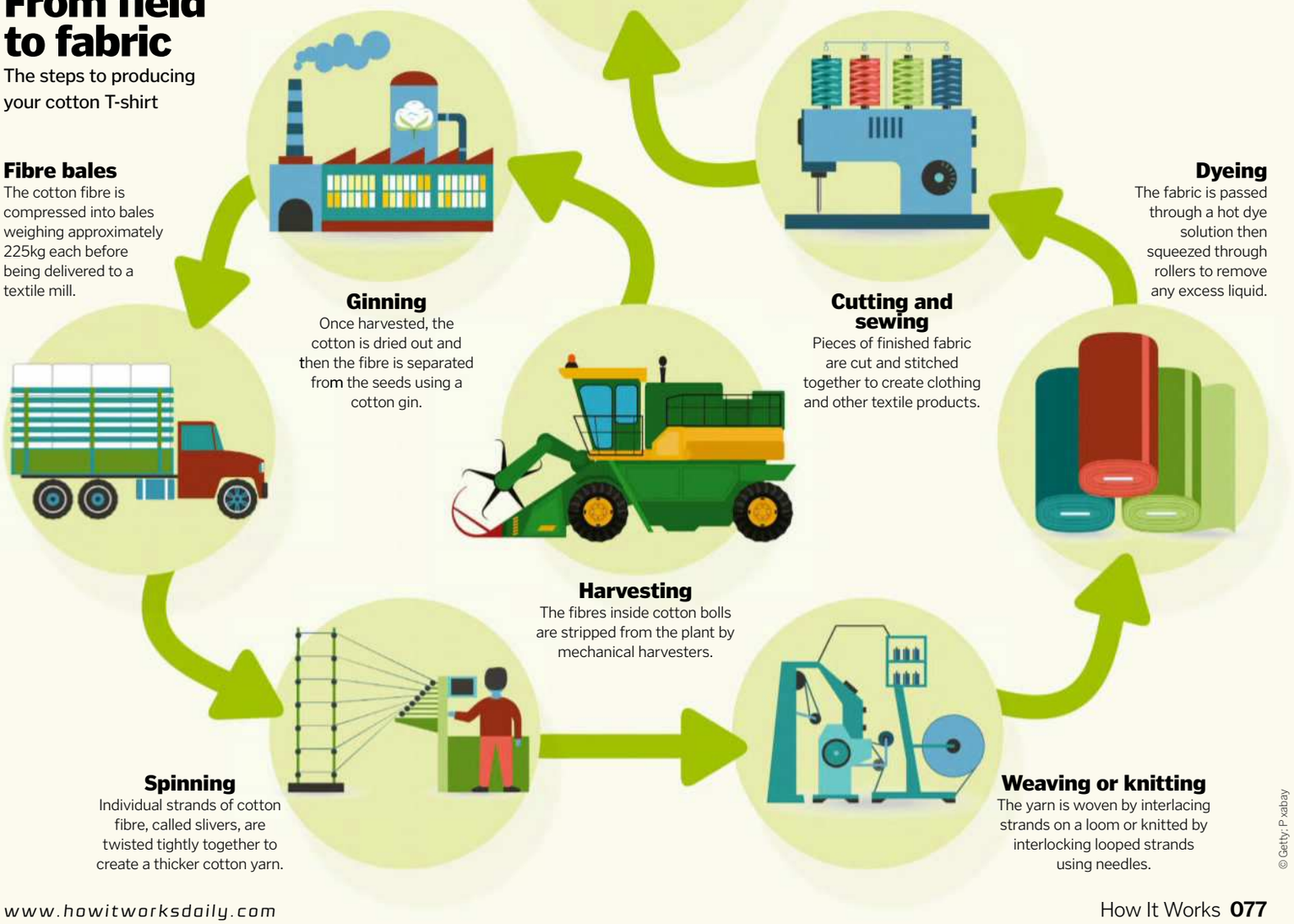
The natural, fluffy fibres of the cotton plant are not all that strong on their own, so they must go through several stages to become tough cotton fabric. First the cotton plant needs to be harvested, which used to be done by hand but is now made much quicker and easier by machines. Stripper harvesters use rollers or mechanical brushes to remove the entire head, called the boll, from the plant, while spindle pickers use revolving barbed spindles to pull the fibre from the boll.

Next, the individual cotton fibres must be separated from the seeds of the plant and spun into strong yarn that can be woven or knitted into fabric. Cotton fabric is particularly practical for producing clothes as it is durable, easily washable and comfortable to wear because it absorbs and releases moisture quickly.

Cotton is grown in more than 80 countries, with over 25 million tons produced every year

From field to fabric

The steps to producing your cotton T-shirt



Ready for the customer
The finished products are ready to be sold to retailers and purchased by the public.

Dyeing
The fabric is passed through a hot dye solution then squeezed through rollers to remove any excess liquid.

Cutting and sewing
Pieces of finished fabric are cut and stitched together to create clothing and other textile products.

Ginning
Once harvested, the cotton is dried out and then the fibre is separated from the seeds using a cotton gin.

Fibre bales
The cotton fibre is compressed into bales weighing approximately 225kg each before being delivered to a textile mill.

Harvesting
The fibres inside cotton bolls are stripped from the plant by mechanical harvesters.

Weaving or knitting
The yarn is woven by interlacing strands on a loom or knitted by interlocking looped strands using needles.

Spinning
Individual strands of cotton fibre, called slivers, are twisted tightly together to create a thicker cotton yarn.

Hampton Court Palace

From Henry VIII's love nest to Queen Victoria's restoration project: inside the 500-year-old royal residence

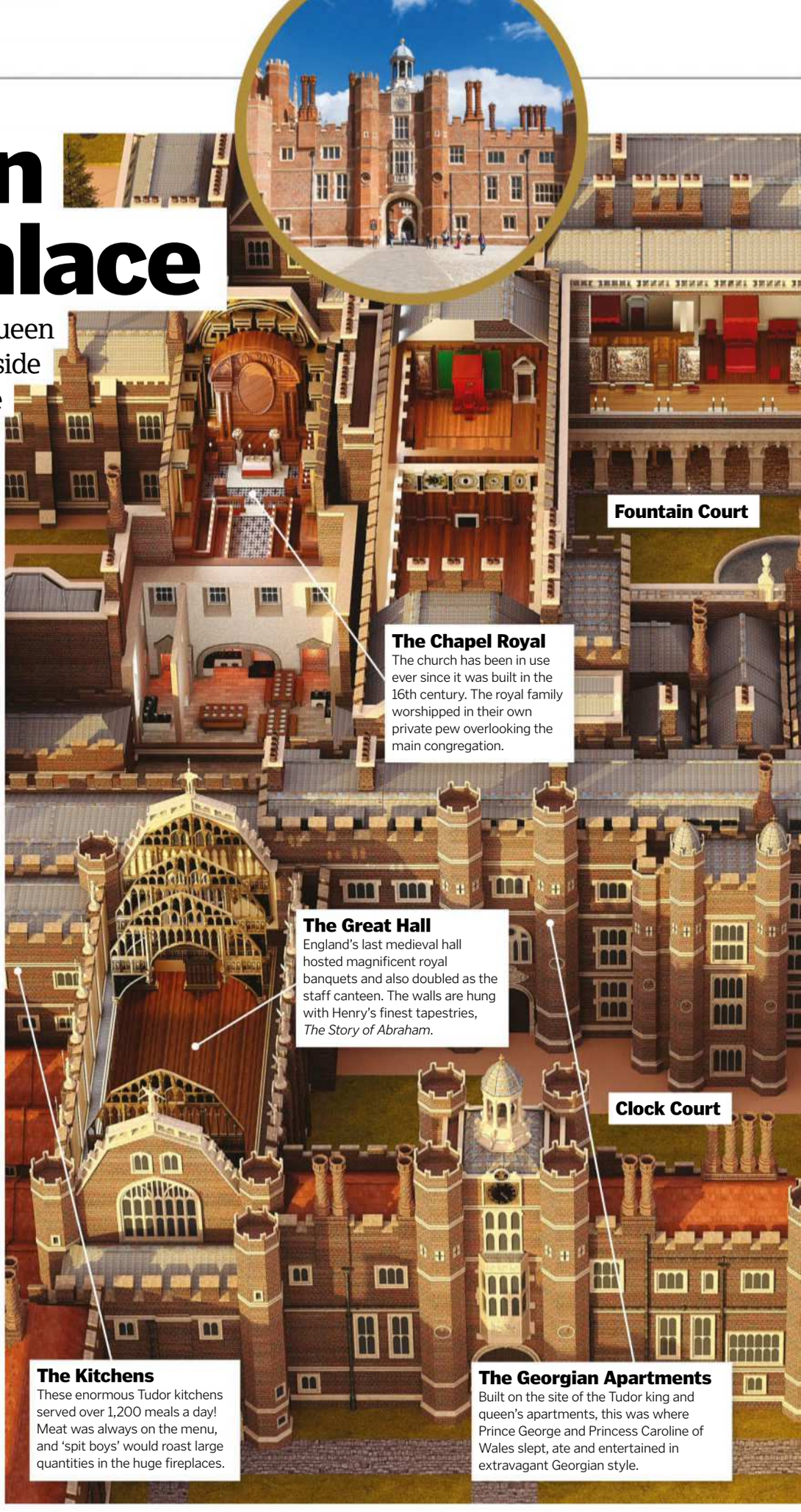
One of England's most treasured historic palaces, Hampton Court was famously home to King Henry VIII, along with his many wives, lovers and scandals. However, the property was originally owned by the monarch's trusted advisor Cardinal Thomas Wolsey, before he was accused of treason and fell from favour, losing his status and stately home.

In 1529, the king and his future queen Anne Boleyn set about making a few royal redesigns. The lovers' initials were carved into the woodwork, and the new queen's lodgings were planned. However, Anne would never use these apartments, as she too fell from the king's grace. After her execution in 1536 Henry ordered that all trace of her be removed, but you can still see an interlocking 'H' and 'A' lying in a forgotten corner of the palace's Great Hall, which the pair had commissioned together.

Beyond this magnificent dining hall lay the king's private chambers, but these were later demolished by King William III and Queen Mary II between 1689–94. By this time the Tudor Gothic style was old-fashioned, so the royal couple commissioned architect Sir Christopher Wren to remodel the palace.

A sweeping staircase leads to William III's State Apartments – a series of grand rooms where he would address high-ranking courtiers. However, the king was happiest in his private apartments, including his personal study and bedroom, all lined with paintings from his collection. William and Mary also built an elaborate maze and Privy garden in Hampton Court's grounds, and they even had chocolate kitchens installed – a relatively new delicacy in England and a luxury only few could afford.

By the Georgian period Hampton Court was in decline. No British monarch lived there again after 1737, and its many apartments were awarded to courtiers – that is, until Queen Victoria ordered the gates to be 'thrown open to all her subjects' in 1838. The palace was so popular that restoration work was gradually carried out to preserve its history, and visitors still come from all over the world to follow in the footsteps of royalty.



Henry VIII's Astronomical Clock depicts the Medieval belief that the Sun orbited the Earth

The King's Staircase
The grand staircase leads to King William III's State Apartments. The king commissioned the Italian artist Antonio Verrio to create the illusion of a magnificent Roman hall.

The Guard Chamber
On the walls are 2,850 pieces of weaponry and armour arranged by King William III's gunsmith. Yeomen of the Guard kept watch at the door.

Great Watching Chamber
High-ranking visitors could proceed beyond the Great Hall and into a series of rooms that led to Henry VIII's private chambers. In this chamber courtiers waited patiently to petition the king.

Base Court
The first courtyard that visitors passed through was home to dozens of courtiers' lodgings. Each had its own fireplace and a garderobe (toilet).

Tudor dining

At Hampton Court you can feast your eyes on the largest surviving Renaissance kitchens in Europe. To cater for hundreds of people twice daily was an immense task, so Henry VIII's enormous food factory was organised into various departments. These included the Master Carpenter's Court, where the supplies were delivered, the Boiling House, where meat was prepared, and the Serving Place, where the clerk of the kitchens would allocate dishes according to the diner's rank.

Without fridges, the Fish Court was used to temporarily store raw ingredients. This was a narrow, outdoor space that ran north to south, so it received little sunlight.

In one year of Elizabeth I's reign the court devoured 8,200 sheep, 2,330 deer, 1,870 pigs, 1,240 oxen, 760 calves and 53 wild boar! This was all washed down with barrels of wine, beer and ale.

A visitor to the Tudor court in 1554 described the kitchens as 'veritable hells'

5 FACTS ABOUT PRIVATE LIVES AT THE PALACE

1 Palace or prison?
After Charles I's (1625–49) defeat in the Civil War, the palace became his prison. He was placed under house arrest in 1649 but escaped through the Privy Garden. He was recaptured and executed.

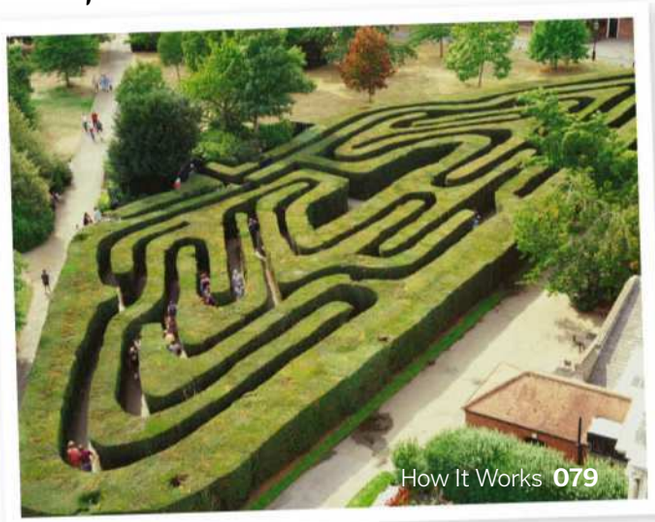
2 Historic hauntings
The Victorians loved ghost stories and claimed the palace was haunted by the spirits of two of Henry's wives: Jane Seymour and Catherine Howard.

3 Royal entertainment
The Stuarts used Henry VIII's Great Hall as the setting for court masques – spectacles of dance, music and drama. William Shakespeare's company, the King's Men, performed for King James I.

4 Luxurious lavatories
When nature called, Henry VIII used a 'close stool' – a padded velvet stool with a hole in the centre and a chamber pot underneath. Lower members of court used a 14-seater lavatory over the moat.

5 A romantic gesture
Charles II commissioned a mile-long canal for his bride, Catherine of Braganza. Swan-shaped boats sailed along it during their honeymoon.

"Queen Victoria ordered the gates to be 'thrown open to all her subjects'"



This maze was commissioned around 1700 by William III. It's the UK's oldest surviving hedge maze

THE STORIES, STRATEGIES, HEROES & MACHINES

www.historyanswers.co.uk

HISTORY of WAR

Available from all good newsagents and supermarkets

ON SALE NOW

Gates to victory: Waterloo > The Kaiser's final offensive > Yorktown > Battle of the Boyne > The Panzer's first strike

GREAT BATTLES | MILITARY MACHINES | HEROES OF WAR | SECRETS & INSIGHT | INCREDIBLE PHOTOS

BUY YOUR ISSUE TODAY

Print edition available at **www.myfavouritemagazines.co.uk**

Digital edition available at **www.greatdigitalmags.com**

Available on the following platforms

Print | Tablet | Phone | Desktop

facebook.com/HistoryofWarMag twitter.com/@HistoryofWarMag


The Sleeping Lady of the Hypogeum is one of the site's greatest treasures

Hal-Saflieni Hypogeum

This subterranean structure is the final resting place of thousands of our ancient ancestors

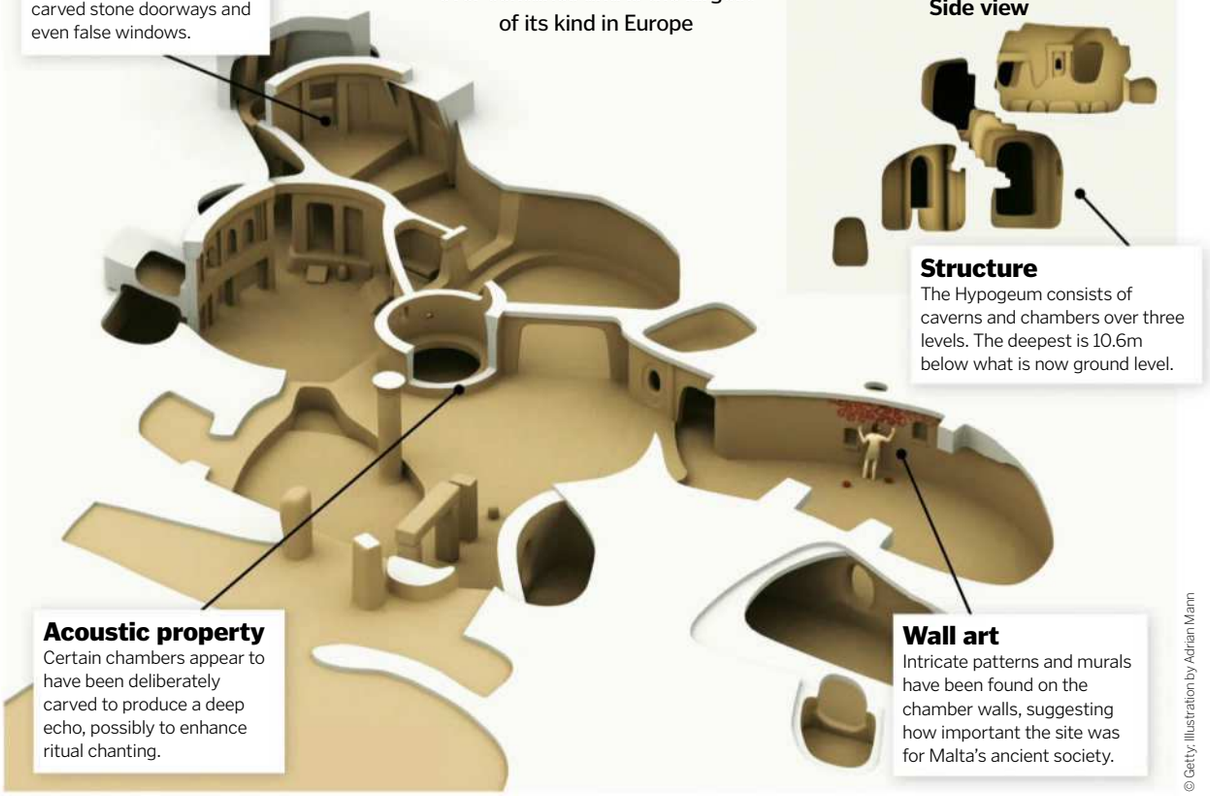
On a hill just a short walk from the picturesque Grand Harbour of Valletta lies the final resting place of over 7,000 ancient humans.

The Hal-Saflieni Hypogeum is a network of 32 underground burial chambers, which date back over 6,000 years. Along with the human bones, a huge variety of statuettes, pottery, jewellery and other possessions were found at the site, suggesting a form of burial ritual. The most incredible find by archaeologists was the Sleeping Lady of the Hypogeum, a stone figurine of a reclining female figure.

The Hypogeum is separated into three descending levels, each carved out over centuries of use. The design of these rooms is similar to Malta's other Megalithic structures, such as the nearby Tarxien Temples, which were used for ritual sacrifice and other ceremonial purposes.

Inside the Hypogeum

This burial site was developed over centuries and is the largest of its kind in Europe



The Gompertz law

How a grim mathematical equation can predict our probability of death

Benjamin Gompertz was a 19th-century financier at the London Stock Exchange with a passion for mathematics and astronomy. Using data from his work in insurance, he created a formula that mapped the correlation between people's age and the probability of their death. For example, when applied to more recent data, his equation shows that after the age of 30 the probability of dying doubles exponentially every eight years. Simply put, Gompertz's cheery law shows that the older we get, the greater chance we have of dying.

Although Gompertz applied his findings to calculate life insurance payments for his company, in 1825 his results were published by the Royal Society, of which he was a member. Initially predicting only the mortality rate in humans, Gompertz's formula was also applied to other species, with varying accuracy.

William Makeham later added to Gompertz's formula, taking into account causes of death independent of age, which created a much more accurate way of predicting mortality rates in relation to age. Even though life expectancy has greatly increased since Gompertz's own death in 1865, experts find his formula still correlates with mortality rates today.

Gompertz Law as depicted on a graph, showing the increasing probability of death with increase in age

The right to vote

Women have been fighting for equal rights for over a century. Here are some of the landmark moments on the road to suffrage

New Zealand

The first country where all women could vote

New Zealand became the first self-governing country to grant the vote to all women. Years of campaigning resulted in a petition signed by over 30,000 women and the passing of the Electoral Act 1893. However, women would not gain the right to stand for parliament until 1919.

United Kingdom

British suffrage begins

British suffragettes were fiercely campaigning for women's rights under the motto 'Deeds not Words' prior to WWI. The Representation of the People Bill was passed in 1918, giving women over the age of 30 who held property the right to vote. Their rights were far from equal though, as men could vote from the age of 21, but it marked the start of women's suffrage in the UK.

Spain

Playing catch-up

Strangely, Spanish women could stand for parliament but couldn't vote until 1931, and they didn't achieve full suffrage until 1976.

France

Celebrating femme-inism

In 1848, France became one of the first European countries to grant universal male suffrage, but women's rights came much later. They submitted their votes in the first general election since France had been liberated in WWII.

Mexico

A Mexican revolution

The decree recognising the full citizenship of Mexican women was published after decades of fighting for equal rights.

Afghanistan

Voting in Afghanistan

Women gained voting rights after the country won independence in 1919, but this was later overturned and not reinstated until 1964.

Grand Duchy of Finland

A new government with no gender discrimination

Over 100 years ago, Finland's electoral system was radically reformed, with both men and women given unrestricted rights to vote and stand for election. Prior to this the majority of adults didn't qualify for suffrage.

United States

All states are awarded suffrage

There were many women's rights groups in America, and different states granted suffrage at different times. It wasn't until the 19th amendment to the US Constitution that suffrage was declared every citizen's right.

United Kingdom

Political equality

The Equal Franchise Act awarded women and men aged 21 the right to vote. It was the result of many factors, including changing attitudes, suffrage campaigns and the example set by other countries.

Japan

First election where women could vote

Men were awarded suffrage in 1924, but women were not. In fact they didn't receive equal rights until after WWII.

Pakistan

A milestone in Pakistan

It wasn't until 1956 that women were allowed to vote and seats in government were reserved specifically for females.

Switzerland

Still fighting for suffrage in the 70s

A national vote was required to change Switzerland's constitution, and when the government finally held a referendum for women's suffrage, it was rejected by the majority of men. The question wasn't posed again until 1971.

Key figures in the fight for women's rights

Emmeline Pankhurst (1858–1928)

This British suffragette and founder of the Women's Social and Political Union was arrested many times in her fight for women's voting rights.

Kate Sheppard (1847–1934)

After migrating from England to New Zealand, Sheppard campaigned for suffrage through writing to the press and public speaking.

Elizabeth Cady Stanton (1815–1902)

Outraged that women were excluded from an anti-slavery convention, Stanton and fellow abolitionist Lucretia Mott held the first women's rights convention in Seneca Falls, New York.

Hermila Galindo Acosta (1886–1954)

Acosta cocreated the feminist magazine *La Mujer Moderna* and helped to influence changes in divorce law through her political connections.

Sojourner Truth (1797–1883)

When Truth gained her freedom after years of slavery she became a leading abolitionist and champion of women's rights. Her 1851 speech, *Ain't I a Woman?*, challenged attitudes to race and gender.

The Mesoamerican ball game

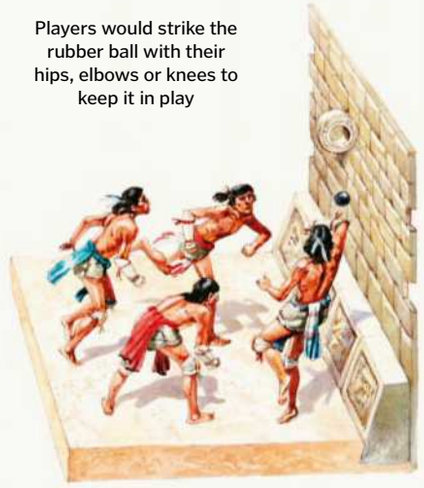
This violent sport was played to appease the ancient gods and had a gruesome twist at the end

Long before the first football match, the ancient peoples of Mesoamerica were playing their own sport, known as tlachtli, pok-a-tok, ollamaliztli or simply, 'the ball game'.

The Aztec, Mayan and other civilisations all played variants of the game, which had first emerged around 1600 BCE. While the exact rules varied across different cultures and eras, it involved a rubber ball and was played between two competing teams on a stone court. What's also certain is the macabre religious significance it held.

The passing of the ball across the court is thought to have symbolised the movement of the Sun through the sky, moving through night to the next day. Carvings found in the remains of the ball courts depict fertility deities, as well as ritual sacrifices, symbolising the transition from birth, through life and into the afterlife. As well as protective garments, players would also dress in the likeness of animal deities in a bid to draw from their strength and skill during the game.

At the end of each match the winning team would be richly rewarded, while the losing side would be ritually beheaded. Spectators also had much to lose at these games, gambling valuable possessions or even their own children on the outcome. This sport wasn't for the faint-hearted.



Players would strike the rubber ball with their hips, elbows or knees to keep it in play

How to play tlachtli

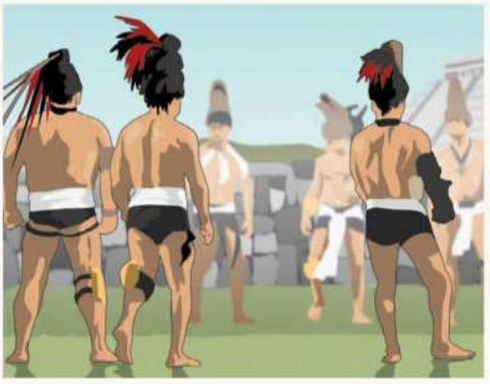
You could lose more than just your pride in this high-stakes game

1 Pick a court

There were many different sizes and shapes of ball courts, but most were rectangular, built out of stone and enclosed by two sloping or vertical walls. Two carved stone rings were also positioned, one on each wall at the halfway point.

2 Make a ball

The playing ball was made of solid latex rubber harvested from the region's gum trees. These balls weighed approximately four kilograms and could cause serious injury to unprotected body parts.



3 Pick teams

Two teams of two or more players would compete, often including members of the nobility or even tribal leaders. Games were regularly held between rival communities, and captured prisoners were also often compelled to play.

4 Gear up

The only certain rule of tlachtli was that players could not play or strike the ball with their hands, only their shoulders, knees, elbows or hips. Strong animal hides were worn as padding to protect these areas from damage.

5 Game on

The aim of the game was to keep the ball in continuous play, with points scored by landing it in sections of the opponent's half. Successfully hitting the ball through one of the stone rings resulted in instant victory for that team.

6 Make a sacrifice

At the end of the game, the winners would receive rich rewards while the losing team would be beheaded as a sacrifice. This was thought to appease the gods, who were believed to control the movement of the Sun through the sky.

STRATEGY GUIDE

Splendor

Buy! Sell! Strategise! Have you got the stones to be a Renaissance jewellery magnate?

This original game casts up to four players as gem traders in early modern Europe competing to acquire precious stones, build a business and gain favour with noble families. It's fast, it's simple and you can explain the rules in minutes, but there's plenty of depth and competition in this straightforward set of rules. You'll need a lot of strategy and perhaps a little scheming to survive.

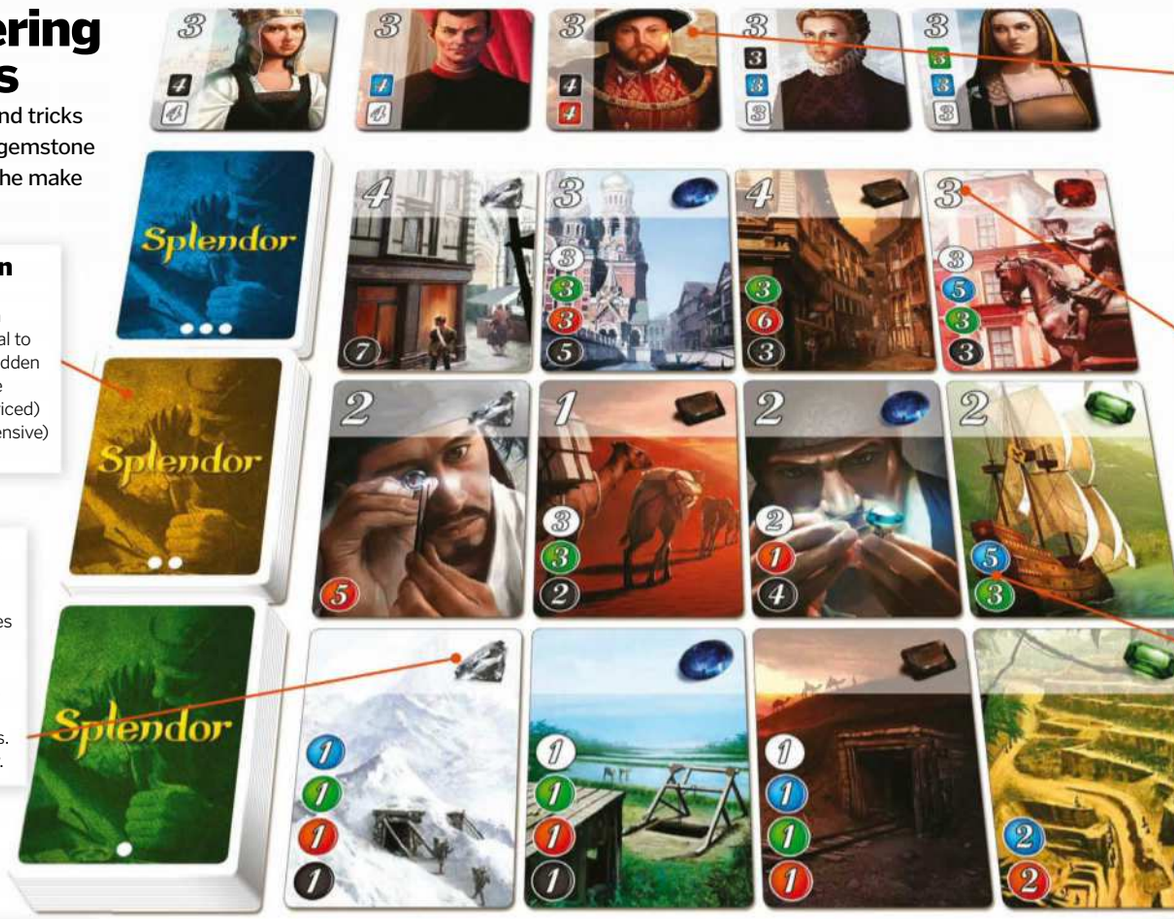
On every turn in *Splendor* you and your opponents choose between a few actions. Do you pick up a handful of the clattery poker chips that represent gemstones? Do you spend your jewels on cards, which offer end-of-game bonuses or discounts on further purchases? Or do you add a card to your hand, reserving it for later and gaining a precious wild card chip? Hit certain combinations and you'll gain an aristocratic client, which means more points at the end.

From these simple choices a quietly devious game is born. You'll assemble a library of cards, each of which makes your own purchases cheaper, but you'll also keep an eye on what your opponents are doing. If they're collecting gems in a particular colour, you'll want to grab those chips first and deny them the opportunity. If they're building towards a big card purchase, nip in and frustrate it by adding the card to your hand. No hard feelings, of course. Business is business after all.

- Publisher: **Asmodee / Space Cowboys**
- Price: **£24.99 / $39.99**
- Number of players: **2–4**
- Ages: **10+**
- Typical game time: **30 mins**

Glittering prizes

Useful tips and tricks for budding gemstone tycoons on the make



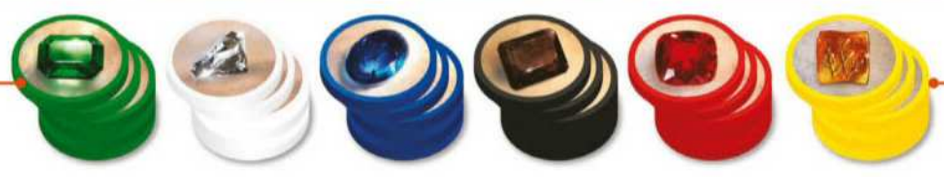
Lords and ladies
Match the totals in the right colours and a noble will grace you with their presence – and their valuable points.

Escalation
Well-timed purchases win games. It's vital to look out for sudden bargains in the yellow (mid-priced) and blue (expensive) card rows.

Numbers game
White numbers indicate prestige: first to 15 wins. Reserving top-level cards early could pay dividends later.

Take it to the bank
Each jewel in your store gives a discount on spending, but cheaper cards don't carry prestige points. Choose wisely.

Closing a deal
Pay the gem cost of each card to acquire it – or snatch the ones your opponents are about to buy.



Raw materials
Choose three chips of different colours or two the same. This is a good way to block someone's get-rich-quick scheme.

Got ingots?
Gold chips substitute for any colour, meaning more strategic options, but you only get them when you reserve cards.

Special offer for readers in **North America**

4 FREE issues

When you subscribe*

"The action-packed science and technology magazine that feeds minds"

Order hotline **+44 (0)344 848 2852**

Online at **https://www.myfavouritemagazines.co.uk/hiwusa**

OFFER EXPIRES 30 June 2018

***Terms and conditions** This is a US subscription offer. 4 free issues refers to the US newsstand price of $9.99 for 13 issues being $129.87, compared with $87 for a subscription. You will receive 13 issues in a year. You can write to us or call us to cancel your subscription within 14 days of purchase. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices are correct at point of print and subject to change. Full details of the Direct Debit guarantee are available upon request. UK calls will cost the same as other standard fixed-line numbers (starting 01 or 02) included as part of any inclusive or free minutes allowances (if offered by your phone tariff). For full terms and conditions please visit: **bit.ly/magtandc**. Offer ends 30 June 2018.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

Who's answering your questions this month?


LAURA MEARS


ALEX FRANKLIN-CHEUNG


TOM LEAN


JO STASS


KATY SHEEN

Want answers?

Send your questions to...

How It Works magazine

@HowItWorksmag

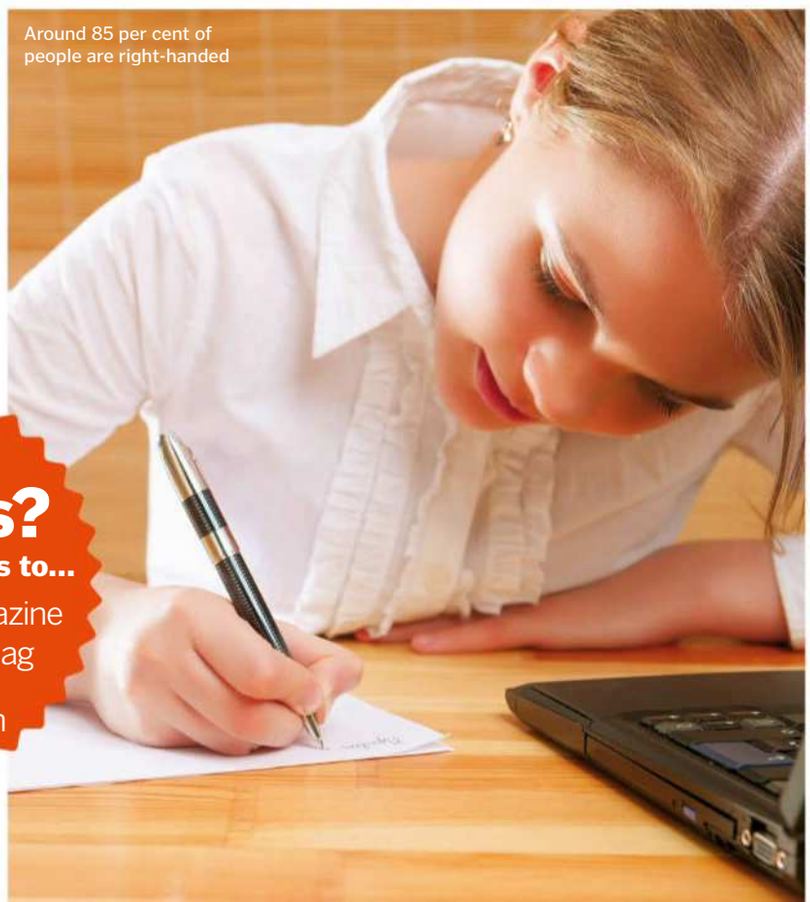
@howitworks@futurenet.com

Pulsars make some of the most distinct 'sounds' to come from space

Does space have a 'sound'?

Mary Marshall

As sound can't travel through a vacuum, space is silent, at least to our ears. Space contains many electromagnetic signals, like radio waves, created by black holes, planets and other sources. Just like a radio set turns radio signals that you can't hear into noises that you can, scientific instruments can convert these electromagnetic signals into sound. So, although space is silent, you can sort of 'hear' it. Different planets and stars even make different 'noises'. **TL**



Around 85 per cent of people are right-handed

Why are most people right-handed?

Kay Taylor

One theory is that as a result of natural selection most people have their speech and language centre in the left hemisphere of the brain, which also controls movements of the right hand. Therefore, producing written language may have become linked with the right hand over thousands of years. Alternatively, hand preference may be genetic, with the variation of the gene that results in right-hand dominance inherited from your parents more reliably than the one for left-handedness. **KS**

The Massachusetts General Court later deemed the witch trials unlawful

What were the Salem witch trials?

Richard Bridges

The Salem witch trials began in 1692 when two young girls in Salem, Massachusetts, began having fits. A doctor blamed supernatural causes, and when other girls began experiencing similar symptoms a group of local women were accused of bewitching them. The women were put on trial and jailed, and soon hysteria spread throughout the community, leading to hundreds more accusations of witchcraft. A special Court of Oyer and Terminer was established, and 20 'witches' were executed over the following months. Eventually Increase Mather, the president of Harvard, denounced the use of spectral evidence, and the court was dissolved in October 1692, although trials continued until May 1693. **JS**

Is it true that bananas are actually berries?

Shane Smith

Yes, bananas are indeed berries, but the reasons why are quite complicated. Botanists define berries as a sub-type of fruit that have an outer skin, a fleshy middle and an innermost layer containing more than one seed. Berries also have to grow from one flower that has just one ovary. Bananas, along with many other fruits you wouldn't expect, like melons and peppers, meet this definition, so they are technically berries. Even so, curiously many fruits that we commonly call berries, such as strawberries and blackberries, aren't berries according to the scientific definition and might be classified as drupes or aggregate fruit instead. **TL**

Bananas are technically berries, however, strawberries and blackberries are not

Which is the world's biggest telescope?

Ashleigh Crane

With a diameter of 10.4 metres, the Gran Telescopio Canarias on La Palma in the Canary Islands is largest single-aperture optical telescope on Earth. **AFC**

Is there a southern equivalent of Polaris?

Harriet Leicester

Sigma Octantis is the closest star to the Celestial South Pole and could be considered a counterpart to the North Star. Unfortunately, unlike Polaris, it is too dim to see under most conditions, meaning it is little use to navigators or stargazers. **AFC**

Who invented sign language?

Sue Matthews

Early man used gestures to communicate before spoken language, but the first official sign language is credited to Pedro Ponce de Leon, a Benedictine monk who used it to bypass his 'vow of silence' in the 1500s. **JS**

Why do we have earlobes?

Jeff Gregory

Earlobes serve no biological function, so we don't really know why we have them, although there is some speculation that they help to keep the ears warm due to their prominent blood supply. **JS**

BRAIN DUMP

Scanning electron microscopy produces 3D images, like this fluff from a dandelion seed

What's the difference between scanning and transmission electron microscopes?

Darryl Jones

■ A transmission electron microscope fires a beam of electrons straight through a thin slice of the specimen, projecting an image, while a scanning electron microscope uses a more tightly focused beam to scan systematically over the specimen, bouncing electrons off its surface. Although transmission electron microscopes are more powerful and can 'see' objects down to just a nanometre in size, a scanning electron microscope produces 3D images and requires a lot less specimen preparation. **AFC**

How does the 'undo send' function work?

Claire Jones

■ Undo-send delays sending your email, giving you time to cancel it before it really gets sent. Or, if it has already sent, it asks the recipient's mail server to delete the message. **TL**

Cats can turn themselves the right way up in mid-air

How do cats always seem to land on their feet?

Rob Guillaume

■ Cats have a flexible spine that enables them to rotate their front and back ends in opposite directions at the same time. As they fall they can rotate their front half clockwise, pulling in their front legs so it spins faster than their back half as it rotates anti-clockwise. This enables them to push against themselves, creating a twist in their spine that swings their back legs round so they can land the right way up. **JS**

Why do sea otters float on their backs?

Mercedes Roberts

Sea otters spend much of their time floating on their backs, which allows them to breathe while performing lots of other tasks, including feeding, nursing their young and even sleeping. **KS**

Why do lots of animals have pale underbellies?

Simon Ashford

It is thought that a dark back and pale belly may act as camouflage. Light usually falls on an animal's back, while the belly is in shadow, but its colouring can even out these differences in light and dark, making the animal harder to spot. **KS**

What's the origin of the superstition of Friday 13th?

Claire Jones

No one knows for sure why so many people are afraid of Friday 13th, but it has roots in ancient history. For example, both the day and the number feature in the Christian crucifixion story. The date likely owes a lot of its modern-day infamy to the 1980 horror film *Friday the 13th*. **LM**

Which is the fastest tank?

Wyatt Lloyd

BAE Systems' CV90 Armadillo can reach 70kph. Its active suspension helps it to pick up speed even on rough ground. **LM**

Want answers?
Send your questions to...
How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

What is greaseproof paper made of?

Vanessa Lawson

In its simplest form, greaseproof paper is just wood. The original manufacturing process involved beating the pulp in order to cram the fibres together. This method, known as calendaring, gets rid of tiny holes in the material, stopping oil from getting in. Today, the paper travels through a series of high-pressure rollers, and it often has a synthetic coating too. A film of plastic or silicone laid over the outside provides an extra greaseproof barrier. **LM**

How do air conditioning systems work?

Tim Bennett

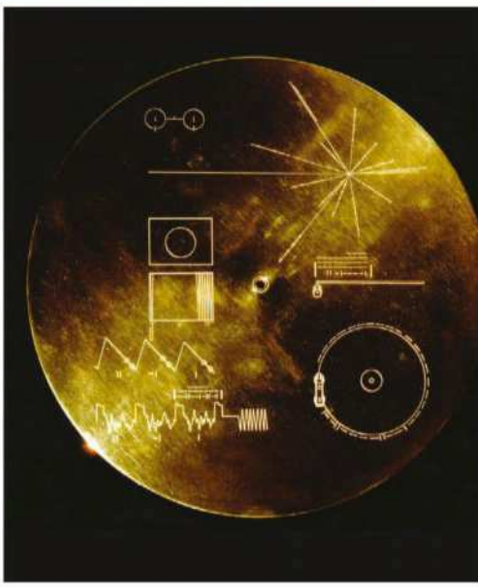
Air-conditioning units have fans and pipes containing refrigerant. As warm air is sucked over the pipes the refrigerant absorbs heat, cooling the air before it's blown out. Absorbing heat turns refrigerant from liquid into gas, which is pumped away to cool back into liquid that is cycled through the machine again. **TL**

Learning to produce a new sound can take many hours of practice

What audio is on the Voyager Golden Record?

Ben Wu

NASA probes Voyager 1 and Voyager 2 left Earth in 1977. They are on their way out of the Solar System, heading into the depths of interstellar space. Each carries a 12-inch record made from gold-plated copper. They play sounds from Earth in case of an alien encounter. The noises include waves, whale song, thunder, birds and people saying hello in 55 languages. There's also 90 minutes of music, including Beethoven's *Fifth Symphony* and Mozart's *The Magic Flute*. There's percussion from Senegal, panpipes from Peru and even some rock and roll – Chuck Berry's *Johnny B Goode*. **LM**



Why does cling film cling?

Brendan Walker

Cling film's stretchiness, combined with a dose of static electricity, allows it to stick to surfaces. Cling film is a thin sheet of either PVC or low-density polyethylene. This plastic's long, coiled-up molecules give it some stretch, allowing it to be pulled taut over plates or bowls. Separating the top layer of film from the roll tears electrons away from the atoms of either surface. Since electrons carry a negative charge, areas that have lost electrons end up with a positive charge, and patches that have gained electrons acquire a negative charge. The patches of electrical charge then stick to anything with an opposing charge. **AFC**

As cling film is unrolled it produces patches of static electric charge

Why can't some people roll their Rs?

Chris McCormick

Producing the rolled 'R' sound in Spanish or Italian feels impossible to lots of language learners. In fact, it is unlikely that there is any physical or genetic reason why a person cannot do this – it may just require lots of practice for some people to get right. The rolled 'R' is a difficult sound to produce as you must hold your tongue in a very specific position and apply the right amount of air pressure as you speak. Young children learning languages with rolled 'R's will often only produce this sound at a late stage in their speech development. **KS**

BOOK REVIEWS

The latest releases for curious minds

How Science Works

A visual guide to the world of science

- Author: **Various**
- Publisher: **DK**
- Price: **£16.99 / $20**
- Release date: **Out now**

Do you understand what string theory is, how it works or why scientists are unsure about whether it's correct? You won't need to wonder much longer, because this is just one of the many questions answered in DK's latest entry into the *How It Works* series (we wonder where they get their ideas!).

The book splits the study of science into five sections: Matter, Energy and Forces, Life, Space and Earth. Into these categories fit a dizzying range of topics, from solids, liquids and gases to travelling to other worlds and climate change.

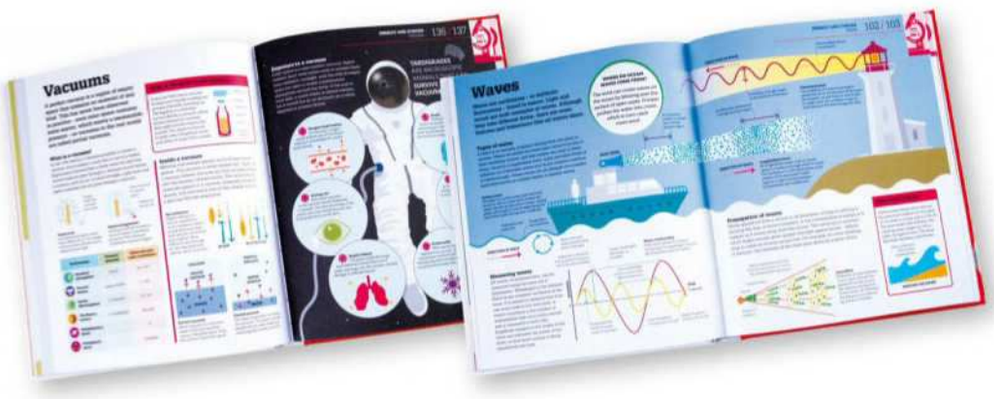
Each topic is explained across a double-page spread, with simple but well-designed graphics helping to illustrate the science behind these complex ideas. The writing and science level on offer makes this the perfect reading material for inquisitive teenage minds or older readers that just want to find out more about the universe that they live in. Each topic is explained clearly and simply, without patronising or ever labouring on a point.

Some of the more complex topics perhaps require a little more than two pages to explain in great detail, but what this book does brilliantly is introduce an idea, get you up to speed on the basics and encourage you to look into it more now that your interest has been piqued.

The graphics really are the standout feature here, helping to illustrate complex ideas in a simple and understandable way. If you've never understood waves, an image of a boat approaching a lighthouse covers waves in water, sound waves and light without every feeling busy or confusing. The design is excellent, and while the illustrations aren't as packed with unique characters as some of our recently reviewed books have been, they do a very good job of including lots of information in an eye-catching way.

This is the latest in a new series of books from DK – you may remember that we previously reviewed the similarly good *How Food Works*. There are others in the series available now and more on the way, which is a great thing to see. Anyone with an interest in learning more about science would do well with this one.

★★★★☆



Everything You Know About Space is Wrong

The truth is out there. Somewhere…

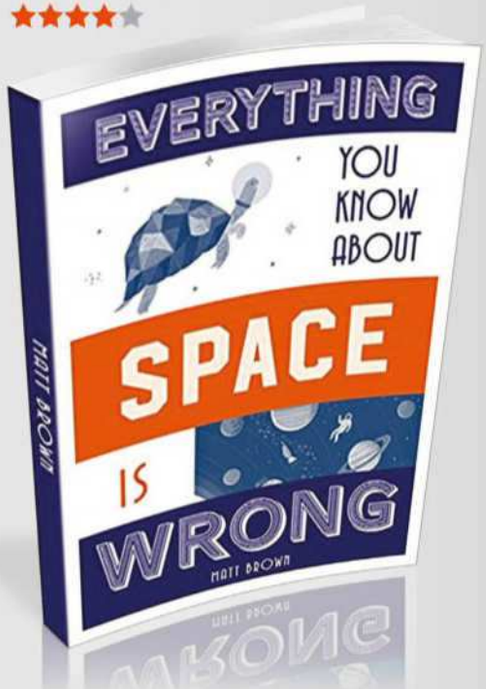
- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 / $12.95**
- Release date: **Out now**

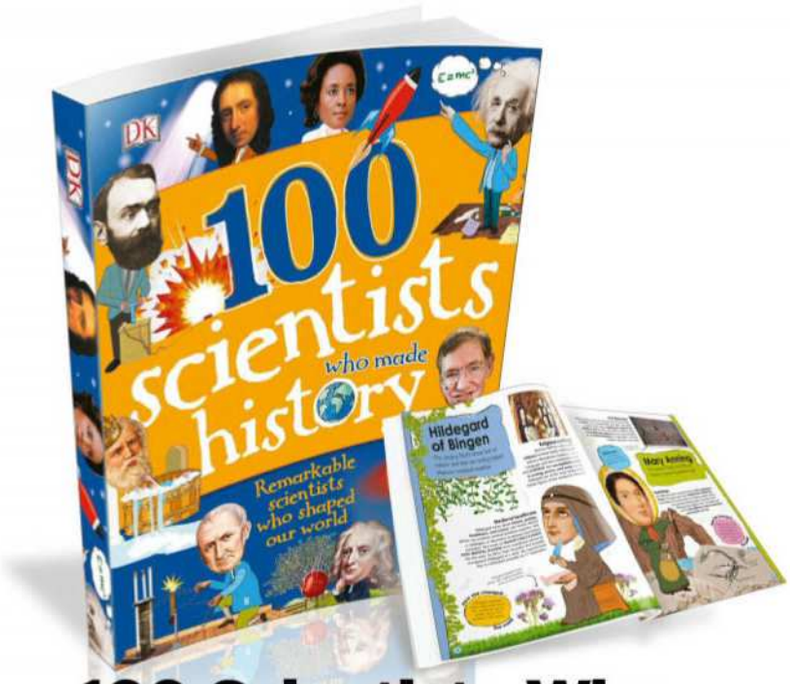
Living in the post-truth era, the importance of discernible facts has arguably never been more paramount, which makes the aim of this book such an admirable one.

Matt Brown doesn't just debunk myths though; he uses them as a means of education, providing building blocks from which to move on to other aspects of the subject matter that may not have necessarily been spoken about that much. This is most appreciated when he tackles theories like the 'fake' Moon landings and what to say to people who think space exploration is an expensive waste of time. Turning a negative into a positive is something we highly approve of.

What you get out of this will depend on your existing bank of trivia – not all of what is said within these pages is as revelatory as the title would have you believe. Even so, this is a bold effort.

★★★★☆





100 Scientists Who Made History: Remarkable Scientists Who Shaped Our World

A century of cleverness

- Author: **Andrea Mills**
- Publisher: **DK**
- Price: **£12.99 / $16.99**
- Release date: **Out now**

With the recent passing of Stephen Hawking having served as a poignant reminder of the great man's achievements, this release from DK is an especially timely one, providing a rundown of other similarly influential scientific figures.

Replete with diagrams and brightly coloured trivia boxes for the benefit of younger readers, the subjects range from well-known figures (Isaac Newton, Archimedes, Marie Curie) to the lesser-remembered likes of Henrietta Swan Leavitt, Inge Lehmann and Avicenna, to more recent innovators like Alan Turing, Rachel Carson and Carl Sagan. If it's a rigorous grounding in genius studies you want, this is a decent enough starting point.

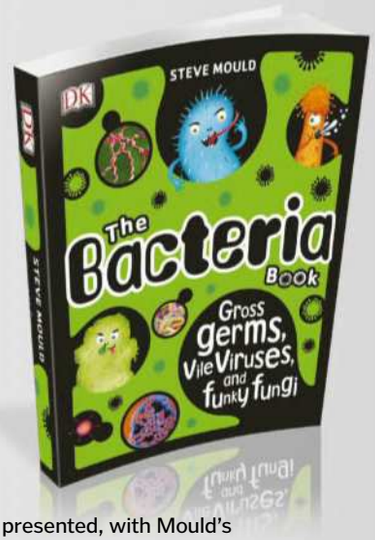
Dorling Kindersley has stood the test of time as a signifier of quality, and this is yet another reason why this reputation is entirely deserved. Chances are you'll more than likely be flicking through this after your kids are done with it.

★★★★★

The Bacteria Book: Gross Germs, Vile Viruses and Funky Fungi

Microscope mayhem

- Author: **Steve Mould**
- Publisher: **DK**
- Price: **£9.99 / $15.99**
- Release date: **Out now**



We've already waxed lyrical about Dorling Kindersley's propensity for producing excellent educational children's books on this very page, and this book vindicates us. Look at the cover: even kids who hate science will want to pick this up!

Penned by Steve Mould (talk about being born to write this book), DK's usual methods to astonish remain. From glowing squids and all the ways you can catch the common cold to superpowered bacteria and micro animals, each topic is lovingly presented, with Mould's commentary a welcome counterpart to the lavish on-page presentations.

A relatively niche topic this may be, but there's not much more that DK could have done to make this superb book eye-catching.

However, it loses a mark purely because DK's other book on this page provides a more comprehensive overview of an arguably more interesting topic. Still, if you can, get this as well.

★★★★☆

Haynes Operations Manual: Siege Warfare

Weapons of mass evolution

- Author: **Dr Chris McNab**
- Publisher: **Haynes**
- Price: **£22.99 / $29.95**
- Release date: **Out now**

The overarching theme of the book reviews in this issue has been rewarding publishers who prize lovingly presented pages working in tandem with a reverence for their subject matter, no matter how niche. It's probably apt, then, that Haynes turns up to the conversation with its own contribution, this time charting warfare's most notable motifs.

From catapults to cannon, it's remarkable how little the basic principles of this particular branch of warfare have changed, despite the numerous advances in technology over the millennia. Taking in not just the subject matter itself but its own discernible impact on the planet's landscape via the physical reminders it has left behind, this is just as much a story of humanity itself as it is a reminder of some of its most sinister excesses.

There's far more depth than you might imagine – but by now we shouldn't really expect anything less from Haynes.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

O	B	A	S	O	L	A	R	S	T	O	R	M	C	G
N	A	G	V	J	A	N	K	I	E	F	H	B	A	L
E	D	I	C	I	B	X	H	P	M	C	G	L	T	T
S	C	L	D	P	A	A	I	R	E	B	I	S	A	R
T	Y	T	K	S	G	N	O	N	Y	L	A	H	R	U
R	C	H	J	L	P	D	B	Z	E	T	X	I	M	O
A	L	C	H	G	I	T	R	O	K	S	B	N	A	C
N	O	A	R	Q	P	U	W	F	D	V	I	J	C	N
G	N	L	Z	B	E	L	U	G	A	L	W	U	A	O
E	E	T	M	K	S	Y	C	J	P	N	R	K	D	T
R	S	F	N	T	O	O	L	S	A	V	Z	U	A	P
O	A	G	O	G	N	D	I	E	Q	A	D	W	M	M
C	U	H	B	V	K	E	S	M	G	O	S	C	B	A
K	F	L	C	M	X	Q	H	A	I	R	E	K	N	H
S	I	S	Y	L	A	I	D	N	O	T	T	O	C	F

FIND THE FOLLOWING WORDS...

AVIAN
BAGPIPES
BELUGA
COTTON
CYCLONES
DIALYSIS
GALILEO
HAIR
HAMPTONCOURT
NAMES
ONESTRANGE-ROCK
SHINJUKU
SIBERIA
SOLARSTORM
TARMACADAM
TLACHTLI
TOOLS

Spot the difference

See if you can find all six changes we've made to the image on the right

Quickfire questions

Q1 In what year did the 'Carrington Event' occur?

- 1885
- 1895
- 1889
- 1859

Q2 Citizen scientists have nicknamed a new celestial light phenomenon 'Steve'

- True
- False

Q3 NASA's 'MOL' programme stood for...

- Manned Orbiting Laboratory
- Manned Orbiter Launch
- Manual Orbital Laboratory
- Military Orbital Laboratory

Q4 Ernest Rutherford's gold foil experiment disproved the _____ atomic model

- Christmas pudding
- Spotted dick
- Plum pudding
- Treacle tart

Q5 Scurvy is caused by a deficiency of which vitamin?

- A
- B12
- C
- D

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		8	3	6	7	9	5	2
9	5	3	1	4	2	8	7	6
			9	5	8	3	4	
				3		6	8	7
8					6	1		5
	6	7		8	1			4
4	1		8	7				9
	3	5	6	2	9			8
6	8				5	7	2	

DIFFICULT

			2	3	7			
	8	9	4					
		5					6	
	4		9	2				
3						1	7	
7	5						4	
	3	1	8	6		2		
6	2			5	3			

What is it?

A .....

▶ Visit our website at **www.howitworksdaily.com** to check your answers!

Get in touch

Want to see your ideas on this page? Send them to...

How It Works magazine @HowItWorksmag

howitworks@futurenet.com

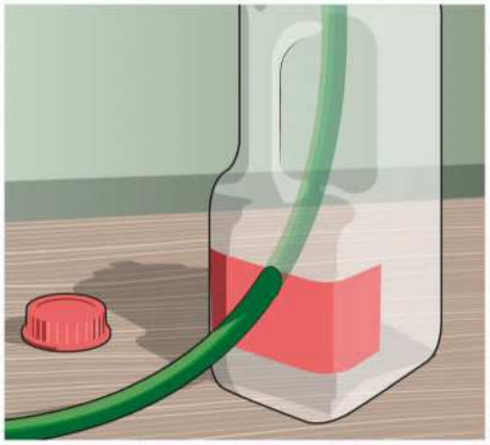
DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

How to build a stomp rocket

Make a rocket that will take to the sky with a stamp of your foot!

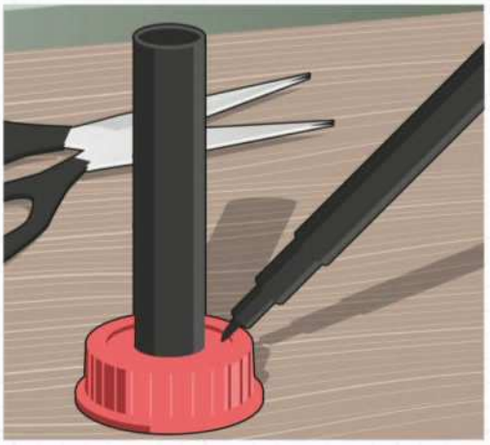
1 Make the pump

To create lift in our rocket we're going to need some air. Start with a two-litre drinks bottle and a short piece of hose less than one metre in length. Wrap some foam tape around one end of the hose until it fits snugly into the neck of the bottle, then secure it with duct tape. Make sure it's attached really tightly, ensuring that no air can escape through the gaps.



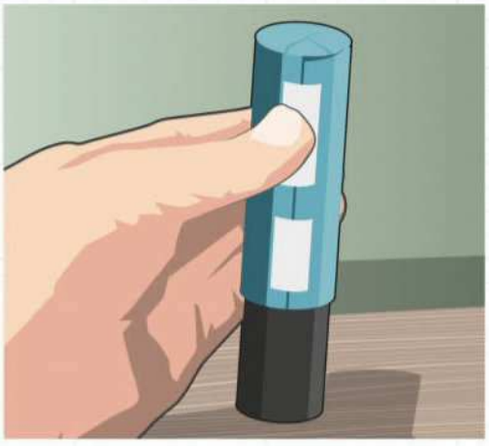
2 Start your launchpad

Next, you need to create a launchpad. Put some pebbles or stones into the bottom of a four-pint milk bottle to weigh it down and carefully cut a hole near the bottom below the handle. Feed the free end of the hose up through the hole and out of the top of the bottle. This will be where the air shoots out and pushes your rocket into the sky.



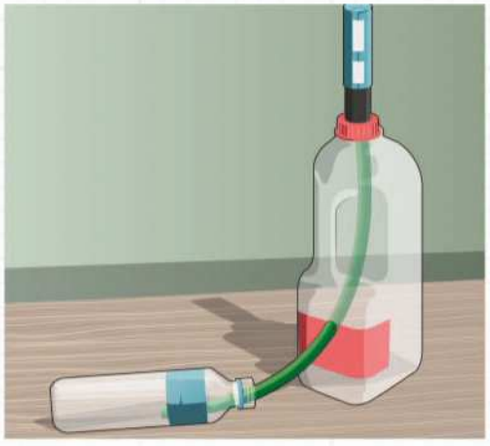
3 Finalise the launchpad

Next you will need some plastic tubing around two to three centimetres in diameter – you can get it from a hardware shop. Ask an adult to saw off the end until you have a piece around 20cm long, then smooth the end down. Draw around the tub on the lid of the milk bottle and cut a hole in the lid so that the tubing will fit tightly inside.



4 Create your rocket

Next, cut a square of thin card around 16cm wide and long, then wrap it around the plastic tubing. Put sticky tape around it like you can see in the image above, making sure there are no gaps. Cut a circle of card out and stick that tightly over the end of the tube. Your tube should be quite a tight fit on the plastic tubing but should come off easily when you blow into it.



5 Ready to launch!

The final step is to put some foam tape on the other end of the hose so that the plastic tubing fits tightly on top, then secure it with duct tape. Put the milk bottle back together, then place your cardboard tube over the plastic tubing and jump on the plastic bottle! Your rocket should shoot into the sky as air is pushed out of the bottle and into the tube.

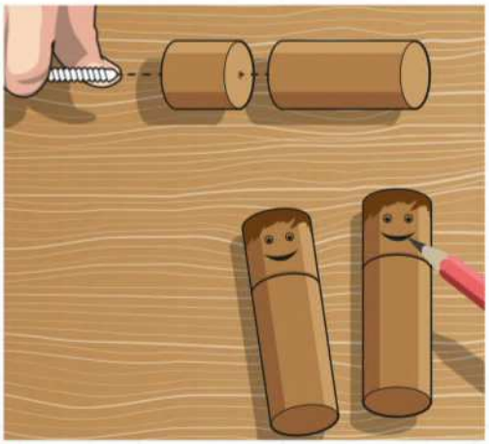
"Your rocket should shoot into the sky as air is pushed out of the bottle into the tube"

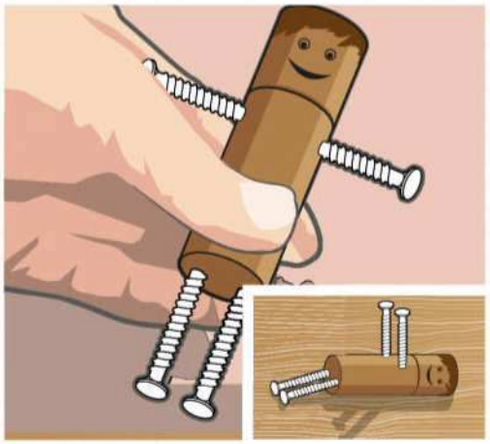
In summary...

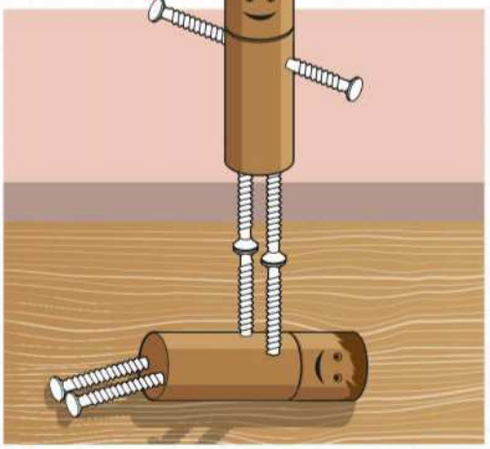
The air inside the bottle is pushed down the hose and into the plastic tubing, and as the pressure quickly builds the air will shoot upwards towards the rocket, forcing it skyward. You could also try adding a cone to the top of your rocket and fins on the side to make it more streamlined.

Make mini gymnasts

These tiny acrobats can perform incredible balancing acts!







1 Create your characters

First of all you need to create your gymnasts. Take some bottle corks and saw one of them in half with help from an adult. Indent the tops of both, then ask an adult to drill a small hole through each of the halves. Place the half on top of another cork, then use a 40mm screw to attach the half to the rest of the cork. Do this again with the other half cork.

2 Give them limbs

Now take two 50mm screws and screw them straight into the bottom of the cork like a pair of legs. Try to make sure the screw heads are both level and flat so that it stands up without falling. Then screw two 30mm screws into the sides. Next, create your 'base' gymnast. Screw two 50mm screws in at an angle so they touch the floor while the gymnast is lying down to stop it rolling.

3 Test and balance

Finally, use two 30mm screws pointing up in the 'base' gymnast to form their arms. These also need to be flat and level and exactly as far apart as the other gymnast's legs. When you stand your first gymnast on the arms of the second it should stand up and balance. You may need to adjust some of the screws to make sure the centre of gravity of the top gymnast is right over its feet.

"Stand one gymnast on the arms of the other – they should balance"

In summary...

This balancing feat is all about gravity. If the weight of the top gymnast isn't directly over its 'feet' then it will topple over, and if the 'base' gymnast isn't solid you'll have similar problems. Once you've mastered this design, try making a gymnast that can balance on one foot!

NEXT ISSUE

FREEZE A GLASS OF WATER INSTANTLY

MAKE MAGNETIC SLIME

Movie buddy

This R2-D2 droid will watch the *Star Wars* films with you and respond to the characters!

WIN!

A SPHERO R2-D2 APP-ENABLED DROID

Sphero's Artoo is the perfect Astromech ally. Complete with realistic movement, LED lights and an integrated speaker, this mini droid has all the characteristic charms of its big-screen counterpart. Artoo can also interact with other members of Sphero's App-Enabled Droid range and will react when you watch *Star Wars* films together.

What is Airbus' extra-large cargo plane known as?

a) **Airbus Tortuga** b) **Airbus Beluga** c) **Airbus Aooga**

WORTH **£129.99!**

▶ Enter online at **www.howitworksdaily.com** and one lucky reader will win!

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to...

How It Works magazine @HowItWorksmag howitworks@futurenet.com

Our understanding of what dinosaurs looked like is continually evolving

Letter of the Month

How to describe a dinosaur

Dear **HIW**,
I find it fascinating that over the years dinosaur bones have been found and assembled, revealing these amazing creatures that once walked this Earth. I would be interested in finding out the process involved in deciding what dinosaurs look like on the outside once the bones are put together. What are the methods used to determine how dinosaurs may have looked? Has anything in the process changed over the years, and just how accurate are the representations that we have today?
Hannah Arney

When the name 'dinosaur' was first coined back in 1842 by palaeontologist Sir Richard Owen it referred to the prehistoric beasts as "terrible lizards". Our understanding of what these creatures looked like has changed a lot since then, thanks to further fossil discoveries as well as improved palaeontological techniques and technologies.
The fossilised remains of a dinosaur can offer a lot of information about how they lived. Teeth, for example, allow us to identify whether an animal was a herbivore or a carnivore. From an animal's diet we can assume other physical traits, like sharp claws for predators.
Technological advances have allowed researchers to also 3D scan bones to form a reconstruction of the weight/volume that could have been supported by the bones. This method was used when exploring the remains of the enormous patagotitan. Indentations or quill barb marks in bones have also led scientists to uncover an abundance of proto-feathers that are now believed to have been a common feature among many dinosaurs.
In rare cases, pigment-carrying organelles called melanosomes can be preserved in fossilised feathers. These cellular structures can provide scientists some clues as to what colours dinosaurs were.
Today's representations of dinosaurs are the best science can depict, but without being able to see them first hand, we may never know exactly what these creatures looked like.

It is estimated that a water bottle can take more than 450 years to decompose

Plastic pest

Dear **HIW**,
I was wondering why plastic doesn't biodegrade and instead remains in our environment?
Jennifer Bland

As a type of polymer, plastics are made from long chains of synthetic or semi-synthetic compounds. In order to form these polymer chains, several shorter chains (known as monomers) are joined together. They are held together by extremely strong carbon-carbon bonds, and it is these bonds that make plastics so durable and non-degradable.
In comparison, a organic matter like fruit decomposes as a result of the breakdown of the peptide bonds between its molecules, a process which microorganisms help with.
As far as we know, no organisms have evolved to break down the carbon-carbon bonds in plastic, which explains why plastic doesn't biodegrade.
However, scientists recently discovered an enzyme that can break down plastic's carbon-carbon bonds (see page 10 for more).

A bum deal

Dear **HIW**,
How has the human body evolved for a modern-day sedentary lifestyle? Are our bums fatter to be comfier?
Derek Carpenter

Our rounded rears are more evolved for walking than sitting. We have the largest backside when compared to any non-human primate. It's believed our buttocks enabled us to remain balanced when we began to walk on two legs.

A hairy question

Dear **HIW**,
I was wondering if you could tell me why people's hair grows at different rates?
Sarah Garibaldi

A lot of what determines your hair's growth rate is down to genetics. On average, human hair grows around 15 centimetres each year, but this rate differs between ethnicities. Asian hair has been found to grow the fastest when compared to Caucasian and African hair, for example. Factors like diet and scalp care can also change your hair's growth.

The worst cut is the deepest

Dear **HIW**,
I would like to know: if a cut is deeper will it heal faster or slower than normal?
Zac Denham

When you get a cut, skin cells and tiny blood vessels are broken, which leads to the wound bleeding. Once the blood has started clotting (which later becomes a scab), the skin cells below begin to multiply and blood vessel connections start to re-grow, a process known as angiogenesis. It naturally takes around three weeks for a typical shallow cut to heal. In deeper cuts or wounds, this process takes longer as more tissue needs to be repaired.

It only takes a few moments for the clotting process to begin once a cut opens

What's happening on... social media?

This month we asked you: what technological advances would you like to see by the year 2050?

"Clean energy or elimination of the plastic in our oceans"
@tancam1983

"I would like to see advancement in health technology. Start curing diseases like cancer, diabetes, cystic fibrosis, auto immune. I think the last disease that was cured was polio"
@Snowfallwinter_

"Personal jet packs to get you from a to b!"
@ActonPhilip

"My son says "visits into space!""
@sarahrob78

"Hover boots. No contest"
@TheeFilmCat

Highlights from the Twitterverse

"Stephen Hawking was our secret key to the Universe. Thank you for leaving the door open"
@dallascampbell

"Happy #taxonomistappreciationday! Last year more than 130 insect species new to science were described from Australia by taxonomists from all over the world! #biodiversity"
@BrytheFlyGuy

"A bizarre, ghostly looking galaxy that astronomers believe to have little to no dark matter was seen by @NASAHubble. This is the 1st galaxy to be discovered that is so lacking in dark matter, which is thought to comprise 85% of our universe's mass"
@NASA

"TODAY I SAW A JACKDAW EAT A SHEEP PLACENTA SO THAT SETTLES IT THIS IS STILL THE AGE OF DINOSAURS"
@juleslhoward

HOW IT WORKS

Future PLC Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Jackie Snowden**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Staff Writer **Scott Dutfield**
Group Editor in Chief **James Hoare**

Contributors
Adam Markiewicz, Adrian Mann, Alexandra Franklin-Cheung, Ed Crooks, James Horton, Joanna Stass, Jodie Tyley, Jonny O'Callaghan, Katy Sheen, Laura Mears, Laurie Newman, Lee Cavendish, Nicholas Forder, Stephen Ashby, Steve Wright, The Art Agency, Tim Martin, Tim Williamson, Tom Lean

Cover images
Alamy, Apple, Getty Images, NASA

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Group Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687368
Media Sales Executive **Jagdeep Maan**
jagdeep.maan@futurenet.com
01225 687353

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

Subscriptions
Email enquiries **contact@myfavouritemagazines.co.uk**
UK orderline & enquiries **0344 848 2852**
Overseas order line and enquiries **+44 (0)344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
Head of subscriptions **Sharon Todd**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Vivienne Calvert**

Management
Managing Director **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Editorial Director **Paul Newman**
Head of Art & Design **Greg Whittaker**

Printed by Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2041-7322

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

FAST FACTS

Amazing trivia to blow your mind

COTTON FIBRES FROM DOMESTICATED VARIETIES ARE THE LARGEST CELLS IN THE PLANT KINGDOM

AROUND

40 MILLION TONS

OF PLASTIC CUTLERY GETS THROWN AWAY EACH YEAR

MALTA'S HYPOGEUM DATES BACK TO AROUND

4000–2500 BCE

THE OLDEST KNOWN FRAGMENTS OF EARTH'S CRUST DATE BACK

4.4 BN YEARS

200,000

AZTECS LIVED IN TENOCHTITLÁN IN 1521, MAKING IT ONE OF THE LARGEST CITIES IN THE WORLD AT THE TIME

GRAPHENE IS

200x

STRONGER THAN STEEL

GALILEO MAY HAVE MADE THE FIRST RECORDED OBSERVATIONS OF NEPTUNE, MISTAKING IT FOR A STAR IN 1612–1613

18,000

THE ESTIMATED NUMBER OF BIRD SPECIES IN THE WORLD

26h 05m 32s

THE LONGEST MARATHON PLAYING BAGPIPES, COMPLETED BY RIKKI EVANS IN AUGUST 2015

THE WIND SPEEDS ON JUPITER'S GREAT RED SPOT CAN REACH

680KPH

THE FIRST TARMAC ROAD IN THE WORLD WAS AN 8KM STRETCH OF RADCLIFFE ROAD IN NOTTINGHAM, UK

MANY DETAILS OF THE NASA MOL PROGRAMME'S TRUE PURPOSE WERE NOT DECLASSIFIED UNTIL **2015**

30

THE NUMBER OF ROUGHLY EARTH-SIZED PLANETS IN THEIR STAR'S HABITABLE ZONE, KEPLER HAS FOUND SO FAR

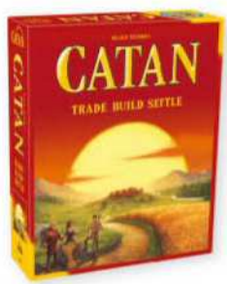
MODERN Classics

Splendor

Travel back to the Renaissance and become a wealthy jewel merchant in Splendor, a card game of clever plans and glittering gemstones for two to four players.

Enter a world of prestige and jewels with this easy to learn and challenging strategy game, rich in historical detail!

PART OF THE MODERN CLASSICS RANGE



AIRFIX®

NEW

QUICK BUILD

Just like the real thing!

Quick, get building!

- Once built, the models have the smooth lines of the real thing, with no brick joiners visible!
- No paint or glue required!
- Cars have rolling wheels with rubber tyres
- Other moving parts included
- Compatible with other plastic brick brands

J6023
VW Beetle, yellow

J6022
Challenger Tank

J6024
VW Camper Van, blue

Head to Airfix.com
to find out more! YouTube

HORNBY HOBBIES
Official Product

9001

0000